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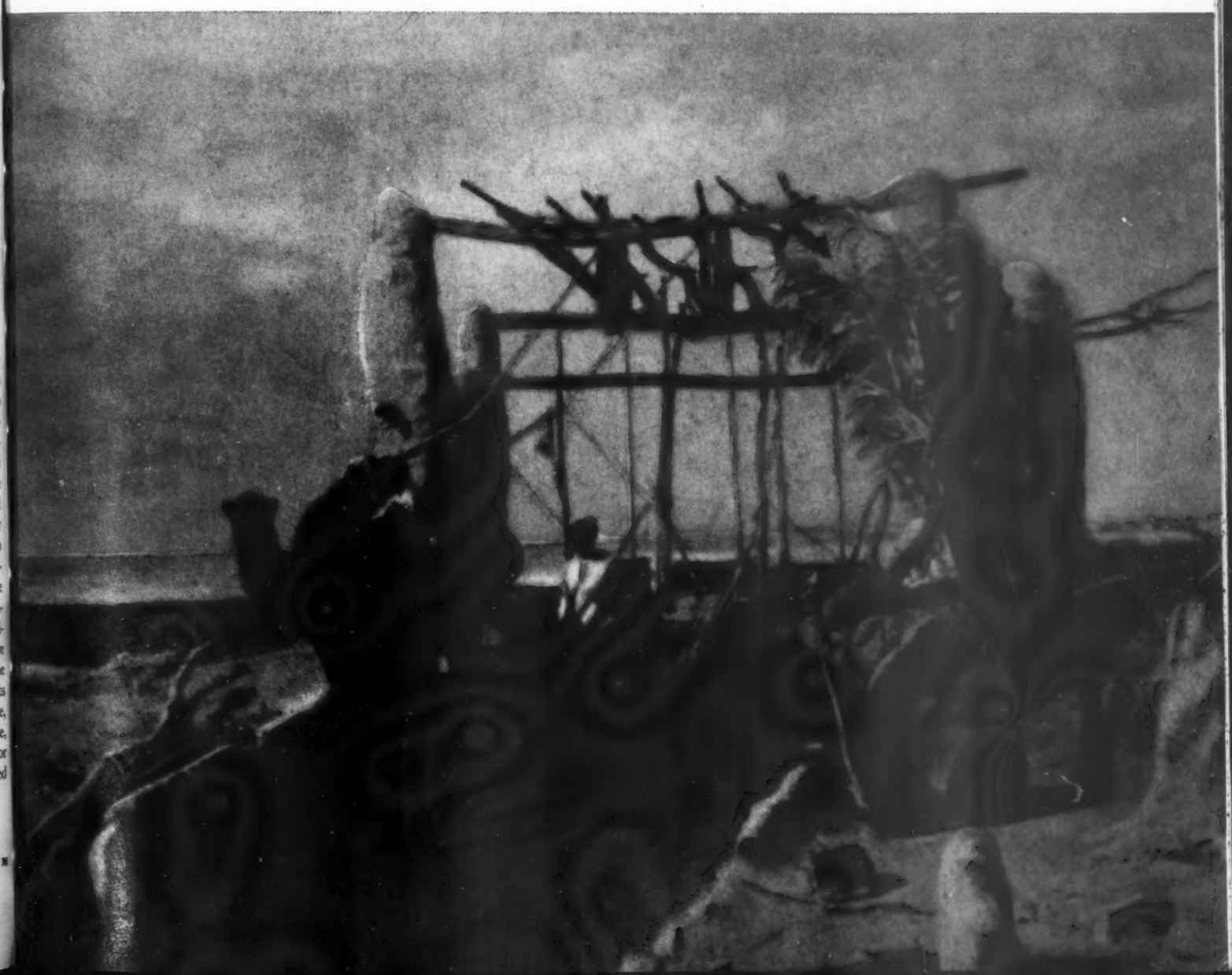
NEW YORK AND LONDON

OCTOBER 1937

THE STORY OF BAHREIN DEVELOPMENT

FOUR MAJOR COMPANIES EXPLORING NEW GUINEA

EARNINGS NEAR 1929 LEVELS



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His Majesty Sheikh Sir Hamad bin Isa Al Khalifah, ruler of the independent kingdom of Bahrein, map of which is shown on the left. The Sheikh's hunting lodge is indicated in the southern portion of the map. Here the court practices falconry and gazelle coursing. Part way up the island to the west are the winter quarters of the pearl fleet. At the extreme northern point of Bahrein is the principal city, Manama, where the Sheikh has his palace, while on the island of Muharrak just off this port the Imperial Airways has established an airfield. The refinery and oil port are shown south of Manama on the eastern side of the island. Thirty miles to the west of the island lies Saudi Arabia, while across the Persian Gulf to the east is Iran.

EDITORIAL

BAHREIN'S PLACE IN WORLD'S OIL PICTURE

IN the history of oil there is no lack of the picturesque and the unusual but one of the most dramatic of its developments in recent years has been the rise of Bahrein to its present place of importance in the international picture. On an island smaller than the average English or American county, the very name of which was hardly known to the western world until five years ago, has come into existence a field that already has yielded ten million barrels of oil from a handful of wells and that ranks among the top dozen producing countries of the world.

Commercially and strategically Bahrein is the outstanding development in the eastern hemisphere since Iraq, and with Iraq it has brought the Near East into a conspicuous position as one of the world's important oil producing areas. Its potential output cannot be estimated because the field itself has not been fully delimited and because the wells thus far drilled are comparatively shallow. One deep test is being put down at present with every indication of large scale production from horizons lower than those previously drilled. Whatever may be the result of this test, enough has been learned to make certain that production will be materially increased and that Bahrein, for many years to come, will occupy an important place on the map of the world's oil areas.

With the completion of the refinery now under construction, Bahrein will become a refining as well as a producing centre and its location is an advantageous one from which to serve the rapidly growing markets bordering the Indian Ocean and the Western Pacific. It fills a useful function also in providing a fuel supply for shipping in its part of the world and its possibilities in this direction have not been overlooked by the British Admiralty.

In the period preceding the completion of the pipe line that placed the oil of Iraq on the eastern shores of the Mediterranean there were doleful predictions as to the effect of dumping this flood of oil on markets already overcrowded and in which prices had been forced to an unprofitably low level. So, in the case of Bahrein, the question has been raised as to where its products were to find an outlet and forebodings have been expressed lest the rapid expansion of its output might upset the markets of the Middle and Far East.

The scare over Iraq proved to be without foundation. By the time the oil from Kirkuk reached Europe a place had been found for it and it was absorbed without a ripple of disturbance. The statistical position of oil today is far stronger than it was at the beginning of 1935. Consumption is putting an increasing pressure upon production and the output of Bahrein, far from being a menace to other marketers, is to be welcomed as relieving, to some extent at least, the strain under which international markets are laboring.

In the first half of 1937 the world production of oil increased over the corresponding period of the preceding year by roundly 100,000,000 bbls. Outside the United States, however, the gain was only 20,000,000 bbls. or about six per cent, while consumption rose by approximately twelve per cent. The growth in production took place mainly in three countries—Venezuela, Iran and Bahrein—while a considerable decline occurred in Roumania, Netherland Indies and the Soviet Union.

Looking to the future it is admitted by all students of the situation that the growth of demand in the United States is proceeding at a rate much more rapid than the extension of supply and that this country will be unable, even if willing, to satisfy the world's increasing requirements indefinitely. Additional sources of production in the Eastern Hemisphere will be urgently needed within the next few years. Bahrein's contribution, while not likely to be sufficient to fill the gap, will be of welcome assistance in that direction.

INDUSTRIAL CITY on a Tropical Island—

The Story of Bahrein

"Fifty Miles Distant From the Arabian Shore Is the Island of Tylos (Bahrein); It Has a Town of the Same Name, and Is Famous for the Vast Number of Its Pearls."

So WROTE Pliny the Elder nearly 2,000 years ago. And only yesterday these pearl beds, long famous even in the time of this ancient historian, yielded first place in importance to the millions of barrels of petroleum which had lain for ages beneath them until brought to the surface by the drills of the Bahrein Petroleum Company.

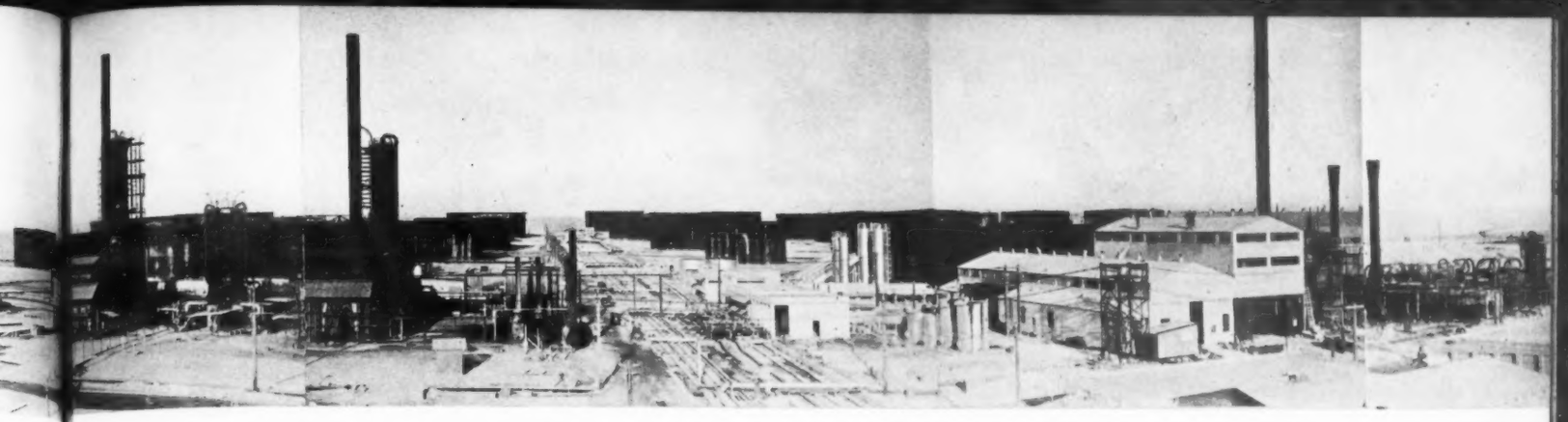
At present this little island 27 miles long and 12 miles across, is the scene of tremendous activity. After nearly six years of prospecting, drilling, development and intensive construction involving an outlay of over $20,000,000, next November will see the official opening of a 25,000 bbl. per day cracking and refining plant and the inauguration of scheduled shipping of products from Bahrein to supply the Asiatic, Indian, African, and Australasian markets of the California Texas Oil Company, Ltd., formed a year ago by a merger of international interests between Standard Oil Company of California and The Texas Corporation.

Drawing its supplies from a zone of British influence and marketing them chiefly in British territories, the Bahrein Petroleum Company has adopted the policy of manning its operations largely with British subjects. Despite the dreaded humid climate of the Persian Gulf the lot of company employees on Bahrein Island is to be a fortunate one, as the air-conditioned houses, hospital, steam laundry, clubs and sports facilities are to be as modern and adequate as is the drilling, refining and laboratory equipment itself.

Bahrein Island is principal among the 14 islands comprising the Bahrein shaikhdom. This independency is ruled over by His Majesty Shaikh Sir Hamad bin Isa Al Khalifah, who owns allegiance to none save for his close treaty relations with His Britanic Majesty. To this friendly power Bahrein owes much in the way of protection and development since it was freed from Portuguese oppression nearly 300 years ago. Today the British maintain a Political Agent with his staff, including customs port and medical officers, a strong naval base and an excellent airport (Imperial Airways). In addition Shaikh Sir Hamad is fortunate in having as advisor to his own government, Charles Dalrymple Belgrave, an English soldier and scholar, whose years of experience among various peoples in Africa adapt him peculiarly to the administrative duties he has had for the past 12 years at Bahrein. Mespers, recently reorganized as Gray, McKenzie and Co., Ltd., and Eastern Brank, Ltd., also have resident British staffs. An American Mission has been maintained on the Island for 48 years by the Dutch Reformed Church.

Representing in every particular the most modern producing and refining equipment and technique known to American practice, the company's operations called for a considerable force of American engineers and operators during construction and first operation. The company, however, is going even beyond its initial commitments in endeavoring to replace Americans with British subjects. Recognizing that a high turnover during the next few years is inevitable an extensive program is now under way in England, aimed at selecting men of ability and character for posts ranging from skilled mechanics to the highest executives. Owing to the great distance of the plant from company headquarters and the type of problems which inhere in any isolated foreign operation the company is making unusual efforts to maintain the highest of personnel standards. It has adopted, moreover, a far-seeing policy which takes into account the possibility of drawing upon the Bahrein organization for experienced and tested men to get other similar projects under way if and when the extensive exploratory and

Burial mounds on Bahrein for which no adequate explanation has as yet been discovered. The mounds are shown in the northwest portion of the Island on the map, page 32; note the size of the mounds in comparison with the automobile.



Panorama of the refinery at Bahrein taken shortly after completion. Right, a striking view of part of one of the units of Bahrein-Petroleum Company's new modern and efficient plant in the Persian Gulf.

development activities now in progress by the same interests in Arabia, Egypt, East Indies and elsewhere are rewarded with further production. Such an outlook cannot fail to attract many young men of capacity and character.

To warrant the interest and loyalty of the high type of personnel sought, the company realizes that it has obligations in return. Unstinted attention is being given to housing, health, recreation and other facilities for the general welfare of employees. While conditions were naturally overcrowded during the construction period, work is under way which shortly will provide every European member of the organization with comfortable and individual air-conditioned quarters.

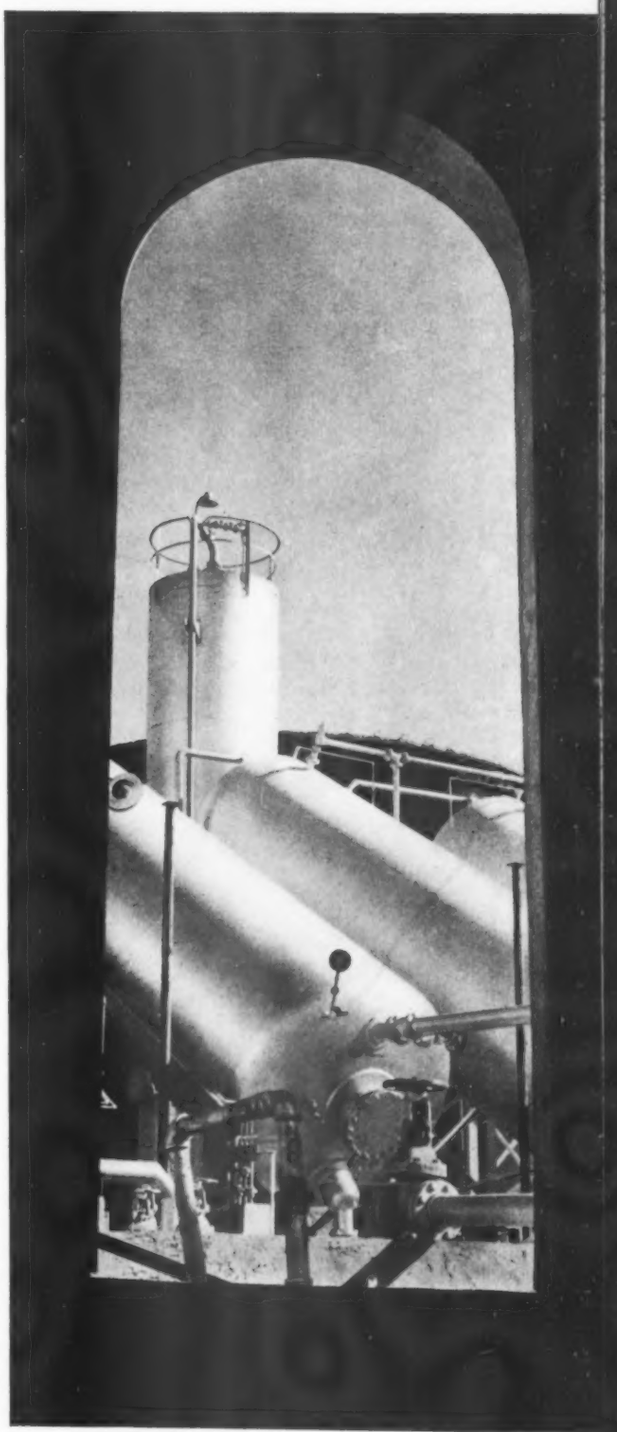
"Bapco City" is situated on the elevated ground close by the edge of the producing field. This location was selected partly for its convenience to the operations and partly for the improved climatic conditions existing here above the surrounding low land of the Island. The first group of 36 five and six room cottages and four and six room bachelor quarters were constructed of native stone masonry with high ceilings and wide verandas, following the usual practice in this part of the world. Experimental work was started immediately aimed at determining what type of building and of air conditioning equipment was best adapted to local conditions. As a result the second group of 35 five room cottages was scientifically designed for air conditioning. They are equipped in every respect to conform to the highest standards of comfort and convenience found in small modern homes in America. The architect who designed these houses has recently been sent to Bahrein to study local conditions and complete designs for extensive additions to Bapco City.

Owing to the isolation of the Island it is essential to provide within its confines for a wide diversity of interests in recreation and general employment of leisure. A comfortable and well equipped club furnishes a bar, reading rooms, and various indoor games. Outside are tennis and squash courts and a large swimming pool. Nearby is a nine-hole golf course and facilities for trap and skeet shooting as well as for cricket and soccer. A few minutes away a beach club, including a fresh water swimming pool to supplement the gulf bathing and a pavilion equipped for picnic suppers, is now under construction. A yachting and out-board motor boat club is being organized. Owing to its healthful nature and the exceptionally fine conditions for small boats, the company is promoting this activity with special interest. The purchase of all necessary equipment for as many employees as choose to participate is being financed by the company. All these recreational facilities, although provided for company employees, are available to other Europeans on the Island.

Among the public buildings is the theater and school house, completely insulated and air conditioned, with an auditorium capable of seating 250. Several modern classrooms and an English school teacher are provided for the children of the community. For adults arrangements have been made through which correspondence courses, covering a wide range of professional and cultural studies, are conveniently available. The theater has the latest type of motion picture projector and sound equipment.

Wives of European and American employees, numbering at present over 80, have been active in organizing social and cultural programs. While this aspect of remote and isolated operations ordinarily receives less notice than it deserves, the company appreciates their profound influence in strengthening and stabilizing the morale of the entire organization and expects to give no less attention to the women's interests than to those of the men.

When the California Texas Oil Company, Limited, was formed the established marketing facilities of those companies affiliated with The Texas Company in Asia, India, Africa and Australasia were taken over in the merger. This means that the output of the modern refinery of The Bahrein Petroleum Company, Limited, will be distributed by the California Texas Oil Company,



Left: The comfortable interior of one of the houses provided for employees on Bahrein and, below, the main camp at Bapco City with cottages, hospital and camp. The refinery is located in the right background.

Limited, and its affiliates, through old and established merchandising organizations which are thoroughly established in the markets and will continue to serve their thousands of dealers and customers.

In addition to the widely established bulk facilities conveniently located throughout the markets, new terminals have recently been erected for the distribution of Bahrein fuel oil and Bahrein Diesel oil. This bunker service already has been widely used by many of the great shipping lines and is a development of prime importance to every shipowner operating in the area.

The construction of facilities for shipping and refining Bahrein oil was started on December 30, 1933, when the Standard Oil Company of California tanker EL SEGUNDO sailed from San Pedro harbor with men, equipment, tools, and supplies to install gathering and loading facilities. The EL SEGUNDO dropped anchor three miles offshore from Sitra Island, which is adjacent to Bahrein Island, on February 22, 1934. She served as headquarters for the construction force that installed the 10 mile gathering system, 250,000 bbl. steel tankage, and a submarine loading system capable of delivering crude oil to a mooring 16,000 ft. offshore at the rate of 5,700 bbl. per hour. On June 7, 1934, 105 days after arriving at Bahrein, the EL SEGUNDO departed with the first cargo of crude oil from the Island.

The speed with which this first installation was accomplished is characteristic of the subsequent construction work at Bahrein. In the summer of 1935, consideration was given to the construction of a refinery, and, in fact, some preliminary design work was started for a crude topping plant. Early in November of that year a definite program for the first unit of refinery construction was approved. This consisted of a 14,000 bbl. crude still, a lead sulfide sweetening plant, an SO_2 treating plant for kerosene, tankage, and necessary auxiliary facilities. The crude still, together with auxiliary equipment required for its operation, was completed June 30, 1936, eight months after its authorization.

During the summer of 1936, the decision was reached to increase the crude running capacity to 25,000 bbl. and to add cracking, reforming, and gasoline finishing equipment, together with their necessary auxiliaries. The construction of any one element of this program within the time allowed would perhaps not be an unusual task, but the procurement and delivery of over 22,000 tons of equipment comprising several thousand items supplied from all over the

world and its erection on a barren island where no skilled labor is available, within the time that is usually considered short for any one part of the project, made the successful completion of this undertaking an exceptional accomplishment.

In order to meet the marketing schedule that was set up by the new company, it was necessary to complete the construction of each refinery unit at the earliest practicable date. The various parts of the program were released for design and construction at different times, but the entire project was completed within 16 months from the date of approval to proceed with the first unit.

The construction project, including practically all the designing, was directed by the Standard Oil Company of California from San Francisco, which is almost exactly half way around the world from the site. Although some of the design work was done by Universal Oil Products Company in Chicago and The Texas Company in New York, all material orders were placed from San Francisco. Aside from sand and stone, practically no materials for construction were available at Bahrein. Some minor items were procured in India, but the bulk of material and equipment had to be supplied from the United States and Europe. In all, over 22,000 tons were delivered to Bahrein between the fall of 1936 and the summer of 1937, about two-thirds of which came from the United States and one-third from Europe. Lumber and considerable fabricated equipment, such as cooling towers, heat exchangers, pumps, and the like, were shipped across the Pacific by way of Bombay, requiring approximately 70 days in transit. Pressure vessels, hot oil pumps, power plant equipment, fabricated piping, and a long list of special materials required for construction of a refinery were shipped from various parts of the United States, across the Atlantic either directly to Bahrein or by way of some European port, requiring between 28 and 50 days. The pressure vessels, ranging in weight up to 116 tons each, and other heavy equipment were transported in specially rigged ships chartered for the purpose. Most of the tankage, cement, fire brick, some of the fabricated piping, structural steel, and many other items were shipped from Europe, where engineering and purchasing representatives were stationed to insure prompt delivery of proper materials for the purpose. Transit time from Europe to Bahrein averaged about 30 days.

To insure completion of the project within the limited time allowed, it was necessary to have a carefully worked out schedule for design, material deliveries, and construction. Every effort was bent toward completing designs in time to permit securing competitive bids, in order to take advantage of world market prices. An important activity was the inspection service that was required throughout the United States and in Europe to insure that materials and equipment of acceptable quality and correct dimensions were supplied, because there is no opportunity at Bahrein to make substitutions out of stock locally available nor are the local facilities adequate for making extensive alterations.

Materials supply was seriously delayed by protracted strikes that occurred in the United States, the flood in the Ohio Valley, and the sudden quickening of business in the United States and Europe, all occurring early in 1937. These delays in delivery threw an unexpected burden upon the construction force toward the end of the program. All materials were received at shipside three or four miles offshore and were transported ashore in barges and native dhows. Most of the pressure vessels were of such dimensions that they were floated ashore, although some of the thicker ones were too heavy to float and had to be handled on specially rigged barges. The larger vessels grounded between one-half and one mile offshore and had to be rolled or skidded from that point to dry land.

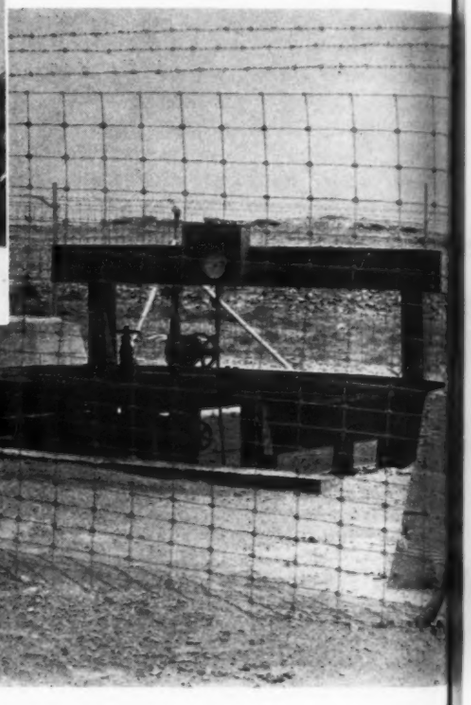
Most of the American engineers and special refinery constructors were supplied by the Standard Oil Company of California.

SUMMARY OF PRINCIPAL PARTS OF BAHREIN REFINERY

PLANT EQUIPMENT	DATE DESIGN STARTED	DATE CONSTRUCTION COMPLETED
Crude still, and alterations to the existing crude still	July, 1936	April, 1937
Two Dubbs cracking units	August, 1936	First Unit October, 1937 Second Unit November, 1937
Reformer	August, 1936	August, 1937
Acid treating plant for cracked gasoline	Sept., 1936	August, 1937
Clay vapor phase treating plant for cracked gasoline	Sept., 1936	Sept., 1937
Acid manufacturing plant, 20 tons capacity	Nov., 1936	June, 1937
Lead sulfide treating plant for sweetening of gasoline and kerosene	August, 1936	June, 1937
Power plant, consisting of two 3,000 kw. turbo-generating sets and two 80,000 lb. capacity, 600 lb. boilers	Sept., 1936	July, 1937
2,000,000 bbls. of steel tankage	July, 1936	June, 1937
Marine loading facilities, consisting of additional pumps and one more sea line to the mooring 16,000 ft. offshore	January, 1937	July, 1937

A moment of relaxation on Bahrein where a swimming pool, tennis and squash courts, golf and trap shooting facilities are provided. Yachting in the Persian Gulf is being encouraged by the company.

Typical of construction work in the East is this anacient and modern combination of an elephant and a steam roller for grading and compacting the earth.



Left: A portable rotary operating on Bahrein; below, a fenced-in flowing well, one of many that have already made Bahrein potentially significant to the world oil industry; right, gathering tanks in the field, whence oil flows to refinery storage.

They were supplemented by skilled mechanics from the British Empire and local labor.

PERSONNEL AT PEAK OF CONSTRUCTION

American engineers and specially skilled refinery constructors	100
British skilled mechanics	200
Iraqi and Indian mechanics	100
Bahreinis	2400
Total	2800

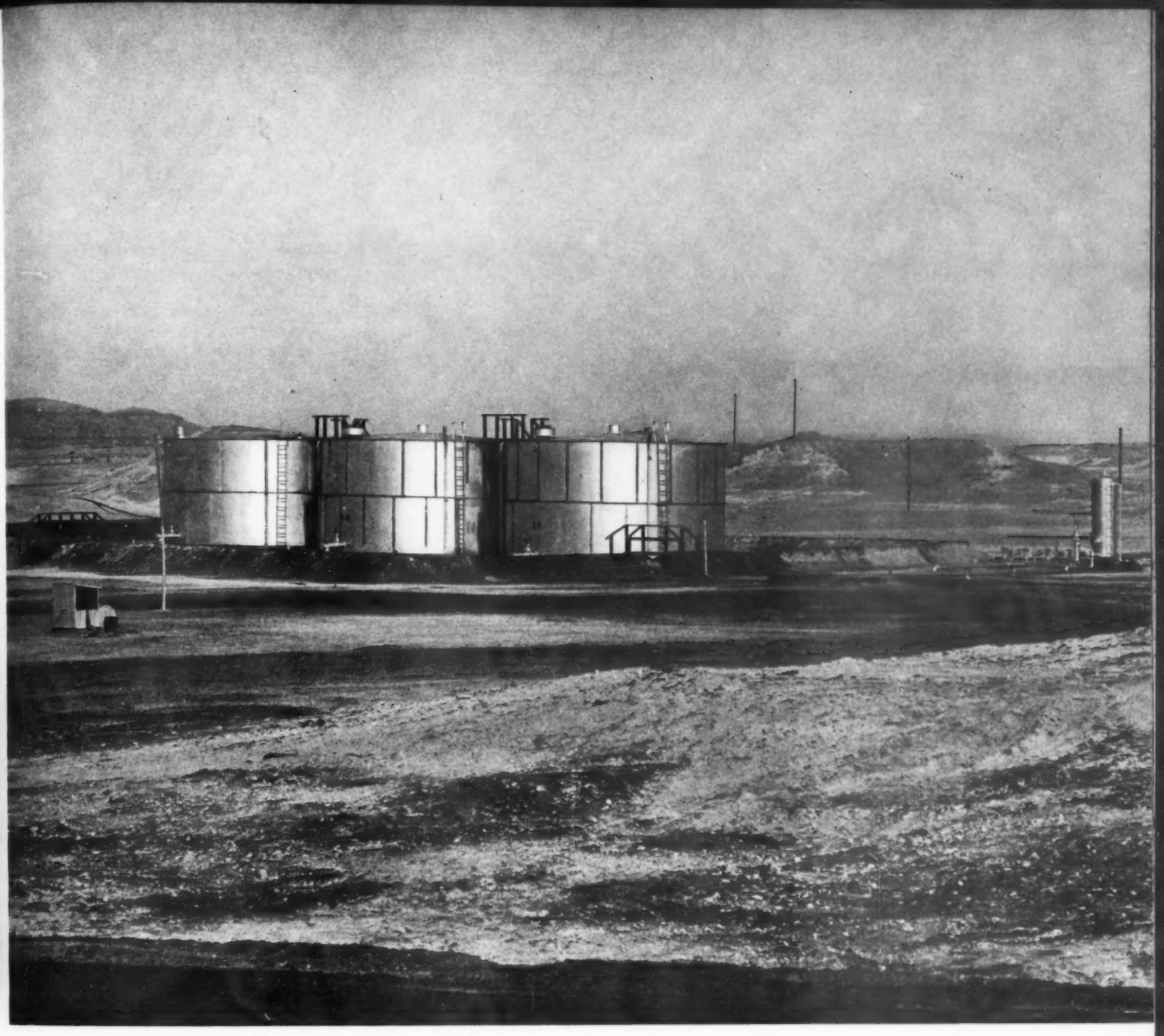
All drawings and instructions to the field were transmitted by air mail from San Francisco, requiring an average of 16 days in transit. More immediate communication was maintained by daily exchange of cables in order to keep the various parts of the project coordinated.

Airplane transportation for personnel was used extensively. Most of the 300 American and British engineers and special mechanics were transported from Europe to Bahrein by plane, in order to conform to the construction schedule. The trip by plane requires four to five days, against two to three weeks for overland travel.

Among a number of interesting problems which called for a combination of modern engineering technology and applied psychology might be mentioned that of fire protection. Always classified among the hazardous industries, a refinery isolated from all outside sources of assistance and manned largely, as to numbers, by inexperienced Arabs and Indians, demands exceptionally careful study. Merely to follow the best design practices and to provide the most modern fire prevention and extinguishing equipment is not enough. The typical native of this region is a curious anomally of fearlessness and fearfulness and is as likely to rush into an explosive area at one moment as he is to flee from a cloud of smoke at the next. A carefully worked out program of typical oil fire situations has been developed with the aim of teaching these employees by actual demonstrations how to avoid fires and how to assist in extinguishing them without undue hazard. Emphasis is put upon a few simple principles: that fires start because of carelessness or breaking rules; that fires can be put out by experienced Euporean operators; that it is safe to go where these operators go and do what they do; and that it is unsafe to go anywhere else or do anything else. To instill such discipline into men who have inherited a racial abhorrence of discipline is itself a problem. An experienced Fire Protection Engineer devotes full time to this and related problems.

The cracking equipment consists of two Dubbs units. Each of the units has a section for heavy oil cracking, light oil cracking, coking, naphtha stabilizing, and gas absorption. The charging stock is made up of fuel oil and gas oil from the crude distillation units and bottoms from the reformer and the clay vapor phase treating plant. The units are operated as two-coil, full flashing, selective cracking and may be regulated to produce either tar or coke bottoms.

Cracking takes place in two furnaces, one of which is charged with bottoms from the main fractionating column and the other with a side cut from the same column. The stock from the furnaces discharges into a reaction chamber and thence into a flash chamber, from which tar is drawn and delivered either to the coking furnaces or to storage. The vapors from the flash chamber go to a main fractionating column from which tar is drawn and delivered either to the coking furnaces or to storage. The vapors from the flash chamber go to a main fractionating column from which the cracked naphtha passes overhead. The feed stock



enters the system at the coke fractionating column. After being preheated in this column by the vapors from the coke chambers, it is fed to the main fractionating column. Coke is removed from the coke chambers with special coke boring equipment and is loaded into dump trucks and hauled either to storage or to the loading terminal for shipment.

The furnaces, which are all of the Equiflux type, were designed by Universal Oil Products Company, together with the other cracking plant equipment, and operate on cracked gas with fuel oil standby. The tubes are of 18-8 chrome-nickel steel and calorized chrome molybdenum steel, designed to resist corrosion at high temperatures. All of the reaction chambers, flash chambers, and the lower parts of the fractionating columns are lined with 13 percent chrome steel sheets. All lines and fittings handling high temperature, corrosive stocks are made of 4-6 percent chrome steel. The charging pumps for the furnaces are of the plunger type and are driven through gears by condensing turbines that operate on 550 lb. steam. Most of the other pumps are of the centrifugal type and are driven by electric motors. A few critical pumps are provided with dual turbine and motor drives so arranged that the turbines will take the load in the event of any electrical failure. Instruments have been provided to make the equipment self-operating in so far as that is practical and to insure uniformity of products.

The reformer unit operates on heavy fractions from the crude distillation units. This plant also includes a Gray treating unit and a stabilizing unit. The general design, pumping equipment, and instrumentation for the reformer unit are very similar to those described for the cracking unit.

The development of the Bahrein refinery power plant well portrays the rapid growth of the entire project. When it was first decided, late in 1935, to build a refinery there was still question concerning its size and type. To suit the modest beginnings it was thought that three 150 kw. generators would meet the requirements. During the progress of design, however, and with the accumulation of data concerning the character of feed water available for producing steam, the power plant jumped to three 250 kw. Diesel driven generators. With the addition of the SO_2 treating plant new demands for both electricity and steam were created. Accord-

condensing cracking plant pumps, the 110 lb. system for miscellaneous pumps, and the 25 lb. system for process requirements.

The discovery well, the first well drilled on the western side of the Persian Gulf, came in at a depth of 2,008 ft. in June, 1932. Orderly development disclosed a field of major size, geologically an elongated anticline, with several hundred feet of producing section. To date 11,000 acres have been proved productive by 50 wells on 3,000 ft. spacing. All wells come in flowing and some have tested more than 20,000 bbl. daily, with an average of about 7,000 bbl. daily. The wells have an average depth of 2,250 ft. and produce from Cretaceous limestone and sandstone.

The drilling history of the producing wells is of interest. Many types of drilling equipment—spudders, cable tools, portable rotaries, steam rotaries, and combination—and all common drilling methods have been compared under unusual conditions. It was found that drilling-in under pressure with

Well No. 1 on Bahrein, the beginning of a strategically located source of crude and refined products in the Middle East; right, the loading pier at Sitrah, shown on the map, page 32.

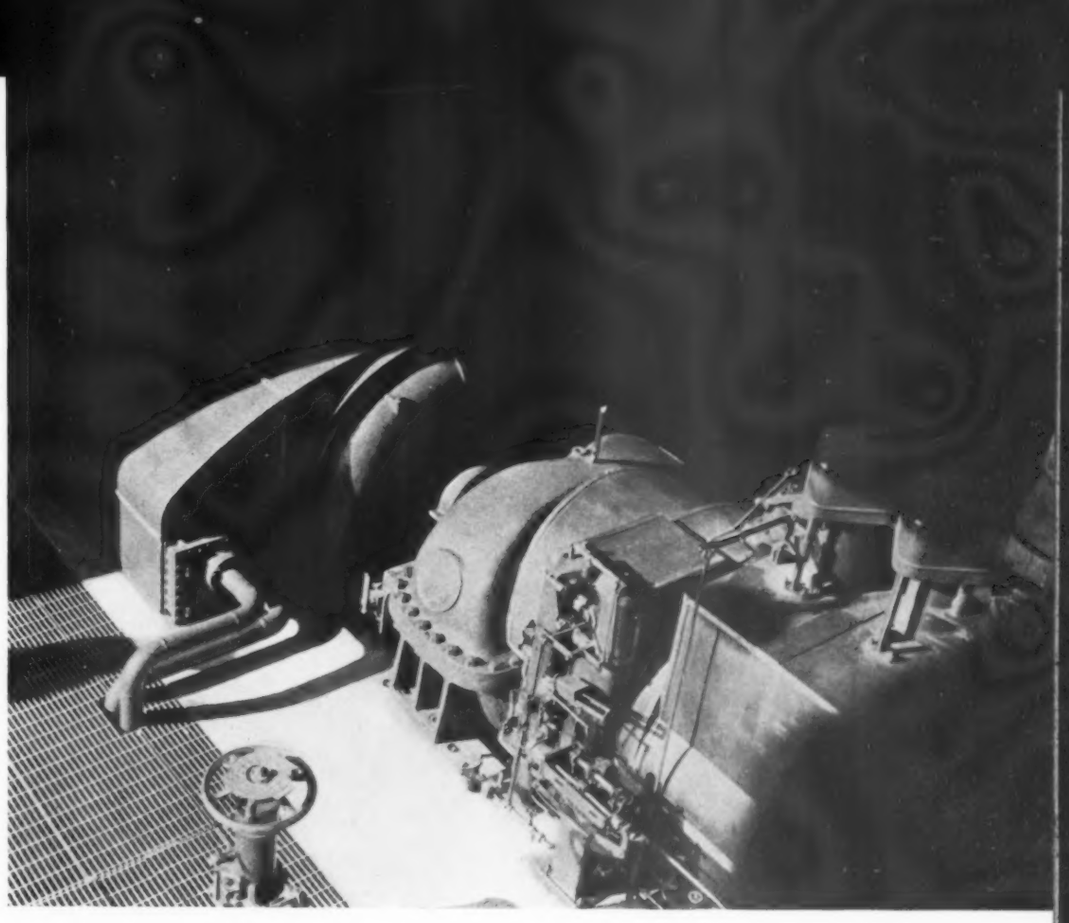
ingly, in spite of the anticipated boiler water difficulties it was necessary to build a steam power plant. For this purpose a 1,250 kw. steam turbine unit and a 40,000 lb. capacity, 600 lb. pressure boiler were added. The turbine was a double automatic extraction machine that supplied the SO_2 plant with both low pressure and high pressure steam that was returned to the boiler hot well in the form of condensate.

The new refinery expansion approved in 1936 changed the entire power requirements. In addition to a very large increase in electrical requirements, there was a substantial demand for high and low pressure steam that could not be returned to the power plant. After the principal demands for power and steam were determined for the new process equipment it was decided to extend the power plant by installing two 3,000 kw. condensing turbo-generator units with double automatic extraction; two 80,000 lb. capacity, 600 lb. pressure boilers; and evaporating plant to provide the refinery with 110 lb. and 25 lb. steam, and the necessary power plant auxiliaries. The requirements were established in September, 1936, and construction of the plant was completed in July, 1937.

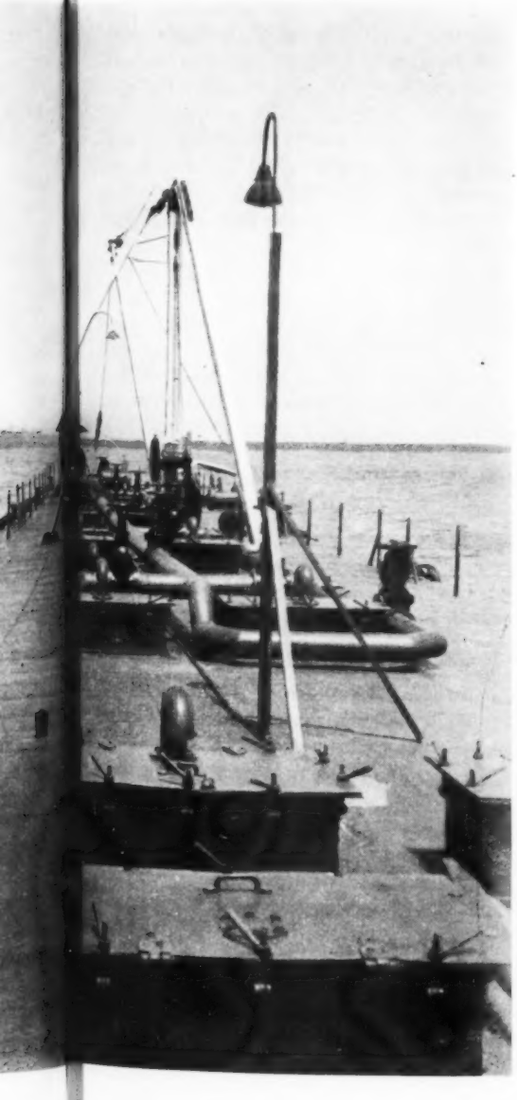
Normally the refinery steam and power requirements will be carried by the 1937 plant addition, and the 2,000 kw. original installation will be used as standby. Estimated demand for the complete refinery is 5,250 kws. of electricity and 120,000 lb. per hour of 600 lb. steam. All of the steam is generated from distilled water and either passes through the power plant turbines or supplies steam to the large turbine driven hot oil pumps at the cracking plant. To meet refinery requirements steam is extracted from the main turbines at 165 lb. and 55 lb. and the remainder goes to the condensers. The 165 lb. bleed steam is fed to high pressure evaporators in which 110 lb. refinery steam is produced from treated, but not distilled, water. The 55 lb. steam goes to low pressure evaporators to generate 25 lb. steam for refinery process purposes.

All power plant equipment is located on the ground floor except the condensers, which are placed in the basement. A steel frame building with stucco exterior and a corrugated asbestos roof houses the turbo-generators, feed and fuel pumps, electric switching equipment, and the boiler aisle, together with the boiler fronts and boiler instruments. The rest of the boilers, together with the forced and induced draft fans, feedwater heaters, evaporators, and water treating equipment are all located out of doors. This construction provides adequate housing for the operators and also protection of less rugged equipment from sandstorms, which prevail in this region. Power is distributed to the refinery at 440 and 2,300 volts and is stepped up to 11,000 volts for transmission to the loading terminal at Sitra and to the camp and producing field. Three different steam systems extend from the plant into the refinery; namely, the 550 lb. system for the large

cable tools was slow because cuttings could not be bailed or flowed off bottom when drilling between pays, also that drilling-in with rotary using weighted mud damaged the pays. This partial mudding off of pay was permanent even though the wells were flowed open to clean up and were thoroughly washed with water and oil. It was definitely proved that drilling time could be cut in half, costs lowered one-third to one-half, and larger wells obtained by drilling the entire hole with rotary and drilling-in under pressure with rotary. A standardized procedure of rig building, moving, and drilling with portable rotaries has been adopted. The first 1,500 ft. of hole is cavernous limestone and is drilled without returns. Drilling-in with rotary, circulating oil and flowing against back pressure, has been entirely successful even when thick shale bodies are penetrated. The location and capacity of the pays are accurately logged, good samples are obtained, and caving is negligible. Liner and tubing are set under pressure.



High pressure turbo generator, part of the power plant capable of producing 6,000 kw.



The cumulative production of the field was approximately 10,000,000 bbl. on July 1, 1937. This oil was produced on a rather irregular production program while drilling and refinery construction work was under way. Production is gathered at five degassing stations to avoid duplication of facilities and evaporation losses. The field is produced at only a fraction of its potential under thorough engineering supervision. The pressure-production characteristics of each well are obtained; complete reservoir pressure surveys are made periodically; water advance is observed in wells drilled for this purpose; all gas production is metered; and pressure-volume-temperature studies are made of the reservoir fluids. Nearly all wells have been acidized to improve flowing characteristics and the resultant average increase in potential is over 200 percent.

All products from Bahrein Refinery are necessarily distributed by marine transportation. Bulk cargoes are pumped from the refinery to Sitra Island, about three miles distant, where shipping tanks and a booster pump station are located at the shore end of the loading lines. The refinery is connected with Sitra by one 16 in., two 12 in. and one 10 in. lines. From here the loading system consists of five submarine lines, viz; three 12 in., one 10 in. and one 8 in. extending three miles offshore to the steel loading docks. These docks, located in 50 ft. of water, have just been constructed. Formerly heavy hose was used for connecting the oil lines to the ships but rather than continue a practice which experience elsewhere has shown to be questionable from the standpoint of contamination in case of hose rupture or leakage, the steel oil lines have now been brought up from the bottom and arranged for normal oil loading practice. Two of the largest ships can be loaded simultaneously at rates up to 6,000 bbl. per hour even for crude and fuel oil.

Steel barges of adequate capacity are available at this terminal for supplying bunkers independently of the cargo loading systems, if required. Packaged goods are transferred by lighter from the company's freight wharf on Sitra Island to the ships.

The harbor is a natural one and well protected. The approach from deep water in the main route up the Persian Gulf is a straight, well marked course having a minimum depth of 40 ft., with 50 ft. at the loading wharf. A lightship is stationed at the entrance to the channel approximately 30 miles from the terminal.

At present most of the tankers in the company's service operate under charter arrangements. The new 12,000 ton Holland-built NEDERLAND, however is company-owned, as is a 17,000 ton tanker nearing completion in Germany. Likewise company-owned are approximately 50 harbor and coastwise vessels for both bulk and package distribution. Marine equipment is under the direct supervision of a Marine Superintendent with headquarters at Bahrein Island, whose staff includes Mooring Masters to assist incoming vessels.

EARNINGS APPROXIMATE 1929 Levels

Despite Lower Prices, Higher Costs

By Henry E. Rose

Fifteen Representative Oil Companies Reported Aggregate Net Profits for First Half 1936 as $61,522,000, Almost Equal to Profits for the Same Companies During First Half of 1929, in Spite of a 20 Percent Decrease in Overall Gasoline Prices, 45 Percent Increase in Labor Costs and 126 Percent Increase in taxes.

ALTHOUGH the American petroleum industry experienced a continuance of record-breaking sales in the three months ended September 30, last, its profits, because of higher labor costs and an unsettled price structure for gasoline in various areas, are not likely to register the same large increase over last year as did those in the first and second quarters.

Exceptions to the general trend will be apparent, however, in several instances, such as Phillips Petroleum Co. and Skelly Oil Co., both integrated companies with more crude production than their refinery requirements, and Plymouth Oil Co., a solely producing company.

Among leading fully integrated companies whose marketing operations have not been affected materially by price unsettlement and whose profits are likely to run ahead of both the June quarter, last, and the September quarter of 1936, may be included Tide Water Associated Oil Co., The Texas Corp., Standard Oil Co. of California, Union Oil Co. of California and Ohio Oil Co. All of these companies report profits on a quarterly basis.

For 27 companies, whose shares are listed on leading securities exchanges, net profits in the first six months of this year aggregated $188,869,440 against $126,274,274 in the corresponding period of 1936, an improvement of 50 percent.

Twenty-one of these companies in the three months ended June 30, of this year, scored a gain of approximately 52 percent over the similar period of 1936 while these same companies, in the March quarter of this year, registered an increase of almost 80 percent over the similar period in 1936.

The two leading West Coast companies, Standard of California and Union Oil, came through the first half with the largest gain in net profits. In large measure the improvement was the result of a bettered price structure in the first three months of this year over the same period of 1936.

Union Oil's net income of $5,200,000, equal to $1.11 a share of common stock this year, was a betterment of 160 percent over the first half of 1936. Standard Oil Co. of California's net of $17,780,190, equal to $1.36 a common share, was an increase of 99 percent over 1936.

Of other major companies which report on an interim basis, Continental Oil ranked in third place. Its net profits amounted to $7,884,529, equal to $1.68 a share of common, an increase of 82 percent over the first six months of 1936. Phillips Petroleum Co., with net of $12,679,080, equal to $2.85 a common share, showed an improvement of 73 percent; The Texas Corp., with officially estimated net of $27,000,000, equal to $2.48 a common share, was up 70 percent; Socony-Vacuum Oil Co., Inc., with estimated $32,000,000 equal to $1.01 a common share, showed a gain of 60 percent. Ohio Oil Co. and Skelly Oil Co. each reported an increase of 53 percent; Tide Water Associated Oil Co. of 45.8 percent; Consolidated Oil Co. of 30 percent and Mid-Continent Petroleum Co. of 29 percent.

Standard Oil Co. of Indiana, reflecting largely an adverse price situation in its territory, showed an improvement of only 27 percent in net profits in the first half of this year—$27,904,211, equal to $1.83 a common share against $22,015,537, equal to $1.45 a common share. The improvement for Sun Oil Co. this year amounted to 26 percent and for Atlantic Refining Co. to 9.6 percent.

Shell Union Oil Corp., mirroring in part the unsettlement in refined products prices in the middle west where it does a substantial business, reported net income in the first half of this year of $8,480,927, equal to 57 cents a share on common stock against $9,301,823, equal to 63 cents a share a year ago. Its 1936 profits, however, included a non-recurring profit of $2,909,807 from the sale of a property. Eliminating this latter item, Shell Union's results, from a strictly operating viewpoint, scored a gain of about 33 percent this year.

It is now evident, even in face of higher operating costs, that the American industry this year heads toward its best profits in almost a decade. Some companies, as a matter of fact, will establish new all-time records, assuming that there are no unusual disturbances during the remainder of this year, such as a severe price recession.

It is interesting, in comparison, to observe how the current year's first half profits line up with those in 1929, the boom year. For 15 identical companies (others did not report on an interim basis in the earlier year), profits aggregated $61,522,000 against $65,799,000 in 1929.

Of these 15 companies, seven this year showed increases over the earlier year and the remainder decreases. Notable among gains are Phillips, whose first half net this year amounted to $12,679,080 against $8,510,807 in 1929; Tide Water Associated Oil Co. with $7,696,701 versus $2,900,652; Continental Oil Co. with $7,884,529 versus $2,200,526; Amerada Corp. with $1,070,106 versus $354,414; Seaboard Oil Co. with $1,230,218 versus $11,456, and Skelly Oil Co. with $3,435,917 versus $3,198,936.

INCREASED EFFICIENCY

It is a tribute to the industry that, despite increasing labor costs and corporate taxes, it has been instrumental in building up its profits in recent years principally because of improvements in the refining art, making possible lower production costs. The price of gasoline, its major money product, has been reduced by 20 percent since 1929, giving no consideration to taxes, federal and state, which have been an increasing burden to consumers meanwhile.

Going back 15 years, the average retail price of gasoline at 14.49 cents a gallon today, before taxes, compares with 24.82 cents in 1922, a decrease of 42 percent. The

cost for refinery labor, contrariwise, during the 15 year period, has increased by 20 percent and working time has been reduced by 25 percent. In other words, the average hourly wage of refinery workers has increased by 50 percent. Taxation has obscured the reduction in the price of gasoline; as has been often said in recent years—"it is not the price of gasoline that is high, it is the tax."

In line with expanding profits this year, the oil companies have been paying out in dividends at the highest rate since 1930, or in seven years. For 21 companies, including Standard Oil Co. (N. J.); Standard Oil Co. of California; Standard Oil Co. of Indiana; Gulf Oil Corp.; Socony-Vacuum Oil Corp., Inc.; Texas Corp.; Imperial Oil Co., Ltd.; International Petroleum Co. and Humble Oil & Refining Co., dividend disbursements so far this year were equal to approximately 71 percent of those paid out in all of 1936.

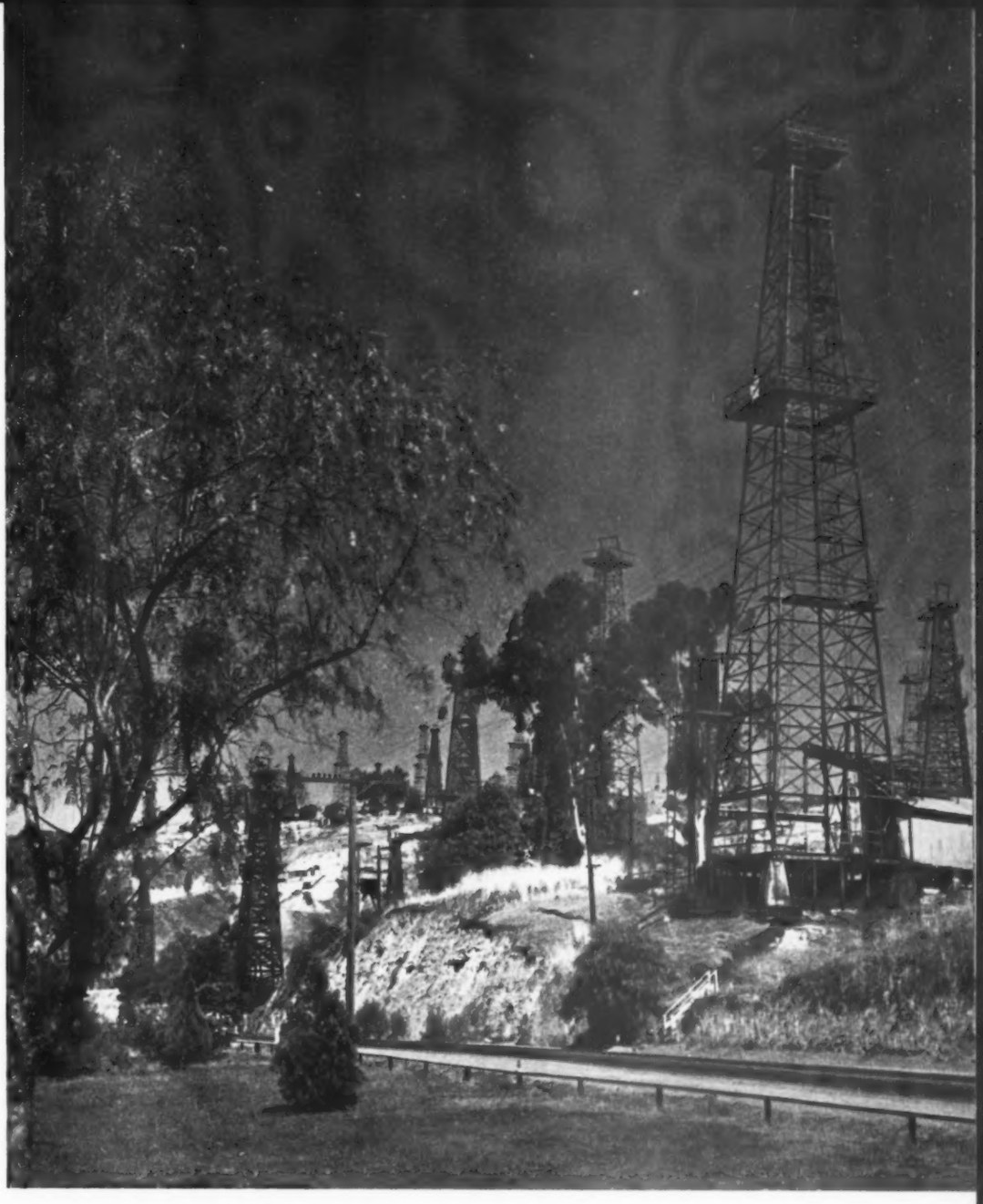
These companies (21) paid out in the first half of this year an aggregate of $203,409,000 as compared with $283,189,000 for the entire year 1936.

Companies in the so-called Standard Oil group paid approximately 23 percent more in dividends in the first nine months of this year than in the corresponding period of 1936, and the largest amount since 1930. Aggregate payments for this group this year approximated $152,000,000 against $124,000,000 in 1936.

As in the final quarter of 1936, when more accurate estimates can be had as to the full year's operating results, and in order to avoid penalties imposed by the Revenue Act of 1936 in respect of undistributed income, it is probable that many companies will disburse extra payments at the year-end. In the 1936 final quarter, dividend payments by companies in the Standard group were the largest for any three months' period in more than 10 years. They aggregated in excess of $114,000,000 in that quarter against only $70,000,000 in the similar three months of 1935.

Evidence that extras will be provided at the year-end is found in the fact that very few companies, in the first half of this year, voted disbursements that approached their reported common share earnings in that period. Skelly Oil Co., for instance, earned $3.22 a common share in the initial six months and paid out only $1.00; Mid-Continent Petroleum Co. earned $1.66 and declared 50 cents; Sun Oil Co. earned $1.90 but voted a distribution of only 75 cents; Phillips Petroleum earned $2.85 and voted $1.25 and Continental Oil earned $1.68 and paid $1.25.

While several companies earlier this year had under consideration plans to make offerings of new securities for the purpose of obtaining funds to bolster their working capital or to refund existing debts, these, for the most part have deferred action on such plans because of uncertainties in the securities markets.



The only important piece of financing to materialize in recent months was the offering by prior subscription to its common stockholders by Pure Oil Co. of $44,244,300 of $100 par cumulative convertible five percent preferred stock on the basis of one share of preferred stock for each nine shares of common stock held.

Proceeds from the sale of Pure Oil's preferred stock will be used as follows: $8,428,200 to retire on January 1, 1938 of 76,620 shares of $100 par eight percent cumulative preferred; $3,000,000 to pay the balance due on bank loans maturing from 1938 to 1940; $25,000,000 to retire bank loans incurred to provide a portion of funds required to redeem the balance of the company's 15-year 4½ percent notes on July 1, 1937; and the remainder for modernizing refineries, developing producing properties and to provide additional working capital. The new financing simplifies the company's capital structure so that there will be outstanding only two classes of securities—common and preferred stock.

Phillips Petroleum Co., which had announced on September 1, last, that it would offer 444,905 shares of additional capital stock to its holders in the ratio of one share for each 10 held, withdrew the offering in mid-September because of the prevailing uncertainty in the securities market.

It was planned by Phillips to use $3,500,000 of the new money to pay certain current liabilities and to set aside $3,000,000 in anticipation of payment of the next maturity of its outstanding joint serial notes due on December 1, 1940. The remainder was to reimburse the company's treasury for capital expenditures and for other corporate purposes.

AERIAL PHOTOGRAPHY Used Extensively in New Guinea Oil Search

Photographic Mapping of 10,000,000, Hectare Concession of Netherlands New Guinea Petroleum Company Nearing Completion—Surface Geological Survey Commenced and Subsurface Studies by Gravimeter in Progress. Field Work Confirms Photo-Geological Interpretation.

THERE ARE NO topographical maps of the interior regions of Netherlands New Guinea in a scale large enough for geologists to work on, so that when N.V. Nederlandsche Nieuw Guinea Petroleum Maatschappij was formed by Netherlands subsidiaries of Royal Dutch-Shell, Standard-Vacuum and Standard of California (participation is 40 percent, 40 percent and 20 percent, respectively) and obtained a concession in Netherlands New Guinea it had to undertake the mapping of 10,000,000 hectares of swamp and jungle within a period of 10 years.

The government of Netherlands East Indies closed its contract with Netherlands New Guinea Petroleum Company, which is under the management of Bataafsche Petroleum Maatschappij, whereby the company received the right for a period of 50 years commencing January 1st, 1936, to explore for and exploit petroleum in areas situated in the part of New Guinea under its rulership to an ultimate total of 1,000,000 hectares. These areas will be assigned out of the 10,000,000 hectares over which the company has obtained exploration rights for a period of ten years. For this purpose it is stipulated that the company shall surrender parts of the territory during the course of the 10 years, within a period of not more than three years at least 2,500,000 hectares, within five years a total of not less than 5,000,000 hectares, and within a period not exceeding 10 years a total of 9,000,000 hectares.

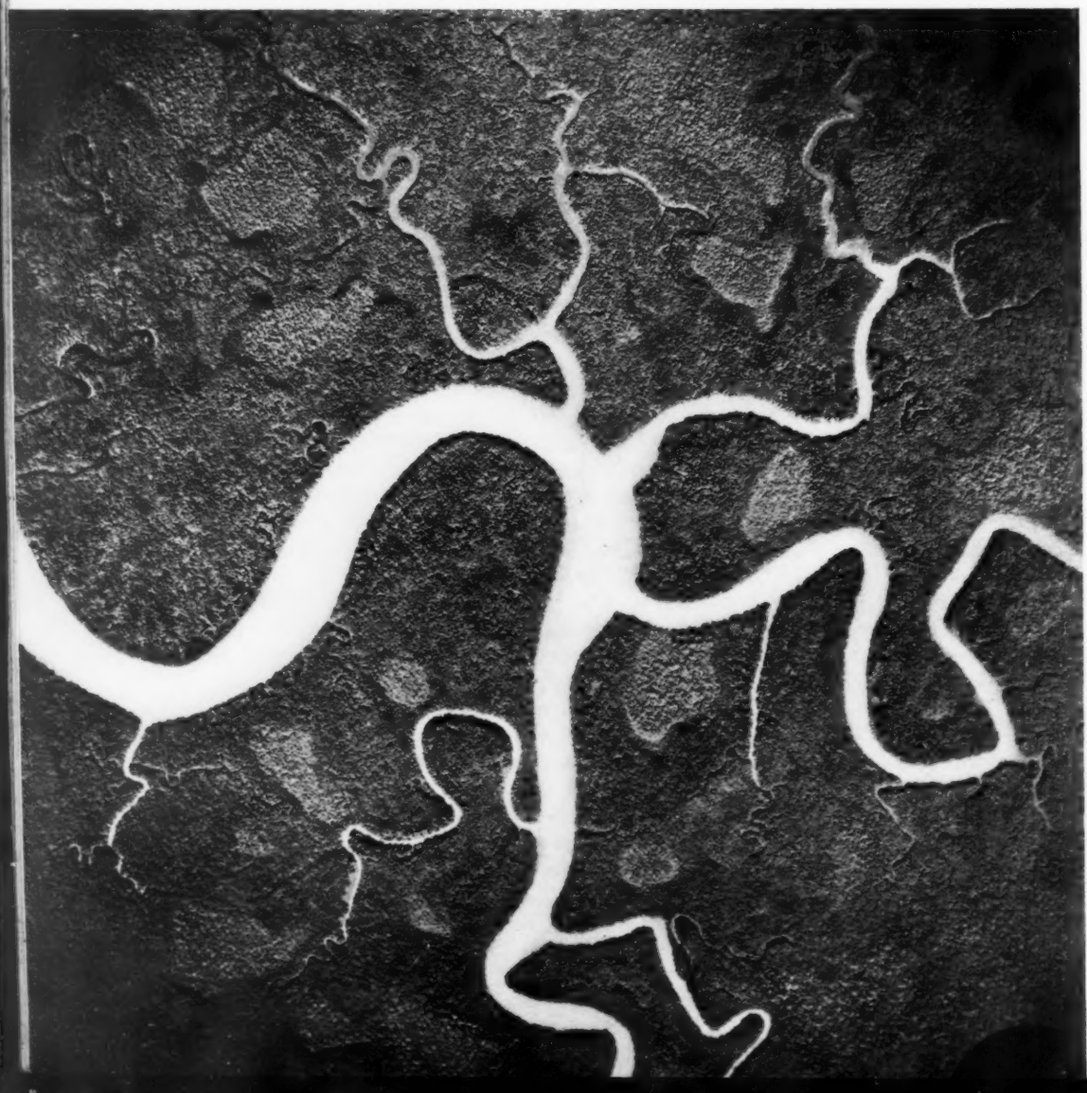
The concession provides that N.N.G.P.M. shall within four years after the expiry of the afore-mentioned period of 10 years submit a report to the government containing the geological data collected during the exploration activities carried out. This report shall be accompanied by a collection of samples of the principal rocks encountered.

As regards the mapping of the areas it is stipulated that a boundry map thereof on a scale of not less than 1 : 25,000 must be submitted to the government within three years after expiry of the exploration period.

Finally the concession lays down that within three years after expiry of the exploration period at least three exploration wells must be started whilst the company is also bound to continue this exploration regularly until at least one exploration well has been started on each separate field.

AIR SURVEY

Since no reliable topographical maps of sufficiently large scale existed of the interior of Netherlands New Guinea, the mapping of the 10,000,000 hectares complex was a matter of paramount importance, in order to provide a map for the geological parties to work on. In view of the extensiveness and inaccessibility of the areas, terrestrial mapping with a cheaply operated organization would have taken too much time. It would have been possible to accelerate the rate of working by extending the organization, but this would have resulted in disproportionately high expenditure. It was therefore decided to map the areas by means of aerial photography. In addition



Aerial photograph of the lower course of a river in the northeastern part of the Vogelkop of New Guinea, clearly demonstrating the advantage of aerial mapping over terrestrial mapping. Many difficulties and a long time would be taken to map a similar area from the surface.

Upper course of a river in the central part of the Vogelkop of New Guinea photographed from the air.

to some further advantages of air mapping over terrestrial mapping, there was another important consideration which led to air mapping being adopted. It was expected that geological study and interpretation of the air photographs would yield data in respect to the geological nature of the territory photographed, which would otherwise only be obtainable by field work on the spot. It may be mentioned here incidentally that the company has not been disappointed in these expectations.

For the air mapping of the areas a contract was closed between Netherlands New Guinea Petroleum Company and N. V. Koninklijke Nederlandsch-Indische Luchtvaart Maatschappij (Royal Netherlands Indies Airways).

After ample discussions between the N.N. G.P.M. and the K.N.I.L.M. it was decided to carry out the mapping work by means of airplanes, provided that it would be possible to find territories suitable for the construction of the necessary landing grounds. Four landing grounds were considered necessary, at Babo, Sorong, Seroei and Mimika.

In December, 1934, a preliminary reconnaissance was carried out during which three of the localities were visited and fields suitable for the purpose discovered; Mi-

Sikorsky-38 amphibians of Netherlands New Guinea Petroleum Company, used in geological mapping from the air.

mika could not be visited owing to lack of traveling facilities. In April, 1935, an expedition was equipped for laying out these landing grounds.

A great many difficulties had to be overcome, but at the end of 1935 landing grounds had been constructed at Babo and on the island of Jefman, near Sorong, while a start was made with the mapping work. At Babo were also erected the headquarters of both the N.N.G.P.M. and the K.N.I.L.M., as it is situated fairly centrally as regards the areas of the complex and is well protected in Bintoeni Bay against the two monsoons.

Endeavours were made also to lay out landing grounds near Seroei and near Mimika for the mapping of the two eastern areas. An excellent landing ground was indeed successfully laid out at Seroei on the south coast of the island of Japen. Some days after its completion, however, it was entirely destroyed by a *bandjir* (flood). Since heavy expense would have been entailed in restoring the ground and protecting it against the danger of further floods, this idea was given up and a decision made to construct a base for amphibians. Along the swampy regions of the south coast area it also appeared too difficult and expensive to construct a landing ground and so bases for amphibians were also constructed there, in the Etna Bay near Aika.

As, judging from the results of the preliminary reconnaissance, it was expected that it would be possible to map the entire territory-complex by means of landplanes, three twin-engined De Havilland-Dragon-Rapide airplanes were purchased, which have been found to be eminently suitable for the purpose. After it had been found necessary to carry out mapping of the eastern areas by means of seaplanes, two Sikorsky-38 amphibians were subsequently purchased for mapping these areas, and these machines have served satisfactorily.

Of the three Dragons one crashed, fortunately without casualties among the occupants. The two other machines, after completion of the part of the work to be done by the airplanes, were taken over by the K.N.I.L.M., who tranferred them from Netherlands New Guinea to Java. The Sikorskys are still operating in New Guinea.

Photographic work is being done with one nine-lens camera (panorama camera) of the Photogrammetrie G.M.B.H., Munich, and three Zeiss wide-angle cameras of the Zeiss Aerotopograph G.M.B.H., Jena.

The panorama camera is a multilens camera with one central lens and eight lenses around this centre lens (focal length of each of the lenses 5.35 cm.). In front of each of the eight lenses a prism is mounted which diverges the rays so that the total angle of view is about 140 deg. The photograph is taken on a negative 18 by 18 cm. which is transformed to a negative of 25 by 25 cm. The transformed negative corresponds to a negative made with a single lens camera with an angle of view of 140 deg. and a focal length of 5.35 cm.

The Zeiss wide angle camera has a lens with a focal length of 10 cm., the size of the picture being 18 by 18 cm., the angle of view 90 deg.

The pictures with the panorama camera are taken on scale of 1 : 80,000, those with the Zeiss camera on scale of 1 : 40,000.

The main purpose of using the panorama camera was to make a navigation map for the flying of the Zeiss camera runs and to use the photographs 1 : 80,000 for the geodetic elaboration, the smaller scale and the wide angle reducing considerably the number of photographs to be elaborated. As, after about 5,600,000 hectares had been covered by the panorama camera, it appeared that for the flying of the Zeiss camera runs the panorama camera was no longer indispensable, it was decided to map the remaining part only with the Zeiss camera.

Photographs by the Zeiss camera are used for the geological-topographical elaboration and for part of the area also for geodetic elaboration.

Along the coast, at distances of from about 60 to 120 miles astronomical stations are observed and ground-marked (20 points in total). These stations and the base lengths measured in their neighbourhood serve as a base for the geodetic elaboration (aerial triangulation). A network of triangulation strips is laid over the area which is tied in to the astronomical stations. The strips are triangulated in the radial triangulator, especially built for the large size negatives, for the part has been photographed with the panoramic camera and they are triangulated in the stereoplanigraph and the multiplex for the remaining parts which has been photographed with the Zeiss cameras only. By this aerial triangulation the coordinates of the principal and auxiliary points of the photographs of the triangulation strips are known.

The geological and topographical data derived from the photographs can be matched between these cordinates.

As already stated the photographs with the Zeiss cameras are taken on a scale of 1 : 40,000. Since the focal distance of the lens of this camera is 10 cm., the flying altitude required is about 13,000 ft. The photographs are 18 by 18 cm., so that a ground area of about 27 square miles is photographed at each exposure. Theoretically, the mapping of the 10,000,000 hectares would be completed in a relatively short time but for the fact that the weather is an important factor. Even with very thin clouds, photographing is impossible because if they are lower than 15,000 ft., which is generally the case, they appear as white patches on the prints and if they are higher than 13,000 ft. they throw shadows on the ground to be photographed. It is consequently necessary for working for the sky to be practically cloudless, which is hardly ever the case in New Guinea. The best time for photographing is between seven and eight o'clock in the morning. The number of minutes that the weather in New Guinea permits of photographing is, according to the experience gained during the air mapping, 30 min. per day on an average. Consequently the mapping will take about two years.

By the middle of 1937 the mapping had been 90 percent completed.

GEOLOGICAL INVESTIGATION

In order to be able to fulfil the contractual obligation to reduce the territory-complex and thus be in a position to surrender an area of 2,500,000 hectares to the Government before January 1st, 1939, a preliminary geological survey is being carried out covering the whole area of 10,000,000 hectares. At the beginning of 1936 a start was made with the regional investigation of the island of Salawati and the Vogelkop peninsula. These areas have been explored systematically, working from west to east, by three parties each consisting of two geologists and one assistant geologist. At present the Bomberai peninsula and the small Manokwari-block are under investigation. In order to speed up the regional investigation the number of field parties will be increased to five. At the same time detail investigations will be carried out on some of the anticlinal structures outlined during the preliminary survey of the Vogelkop and Salawati, in order to get locations for a deep test.

Before the geologists leave Babo for the areas to be investigated by them, the air photographs of the respective territories are studied by the so-called photo-geologists and geologically interpreted. The photo-geologists study the Zeis photographs with the aid of the mirror stereoscope. The geological and topographical data are drawn from the photographs on tracing paper of highly transparent quality (Koda trace).

Data of from four to eight adjoining photographs are drawn on one strip of tracing paper. Of each strip a number of points is known in co-ordinates These points are mapped according to their co-ordinates on drawing paper to a scale of 1 : 40,000 and the tracing strips are matched between them.

Along the same principles a map of 1 : 100,000 scale is made.

Field geologists go into the field with these maps, on which all the geological and topographical data are drawn that could be derived from the air photographs. Moreover they take with them a set of photographs and a stereoscope so that they are able to check the data in the field.

This photo-geological interpretation work has been found to be of great assistance to the geological field work and has revealed various structures which were confirmed by field work.

A palaeontological laboratory has been erected at Babo for examination of rock samples collected by the geologists.

GEOPHYSICAL INVESTIGATION

Of the 10,000,000 hectares forming the territory of the N.N.G.P.M. only 6,000,000 hectares are hilly ground and about 4,000,000 hectares are covered by swamps and alluvial plains. Investigation of the latter can therefore only be carried out by means of geophysical methods. With the Holweck pendulum a regional gravity survey of the entire territory was commenced in June, 1936, for the purpose of obtaining a general picture of the geological structure of the subsurface. The structural indications thus obtained are being checked and detailed by torsion balance investigations.

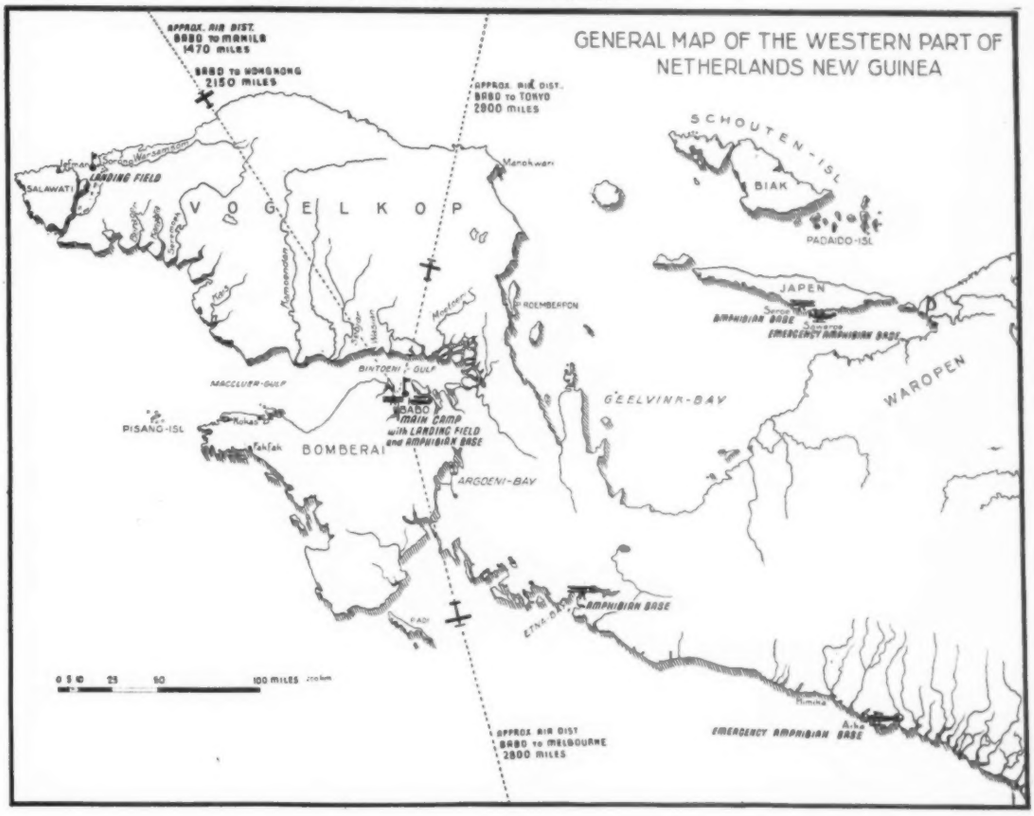
HEALTH AND POPULATION

Although New Guinea is known to be very unhealthy (malaria) the N.N.G.P.M. has succeeded in confining the number of cases of sickness to a minimum by means of hygienic precautions and medical attention. Thanks to airplanes being available patients in the case of accidents or sickness could moreover always be transported speedily to the hospital at Babo, so that, where necessary, measures could be taken by the medical staff almost immediately.

Attitude of the natives has up to now been almost consistently friendly. In some cases where the appearance of the Papuans gave cause for uneasiness a tactful attitude always circumvented difficulties.

If the oil exploration of Netherlands New Guinea proves to be successful this will be a reward not only for the enterprise of the oil companies and the pioneer work carried out by their employees, but will also benefit the native Papuans by increasing the influence of civilization hitherto almost limited to the coastal regions.

The Netherlands New Guinea Petroleum Company has undertaken the aerial mapping of 10,000,000 hectares (38,600 sq. mi.) of swamp and jungle.



The Oil Engine, London

Brilliant lighting partially derived from crankcase drainings at this Milngavie, Glasgow, garage is an aid to the salesmanship which appealed to the economically minded Scots business man.

ELIMINATION from the Retail Market of RECLAIMED LUBRICATING OILS

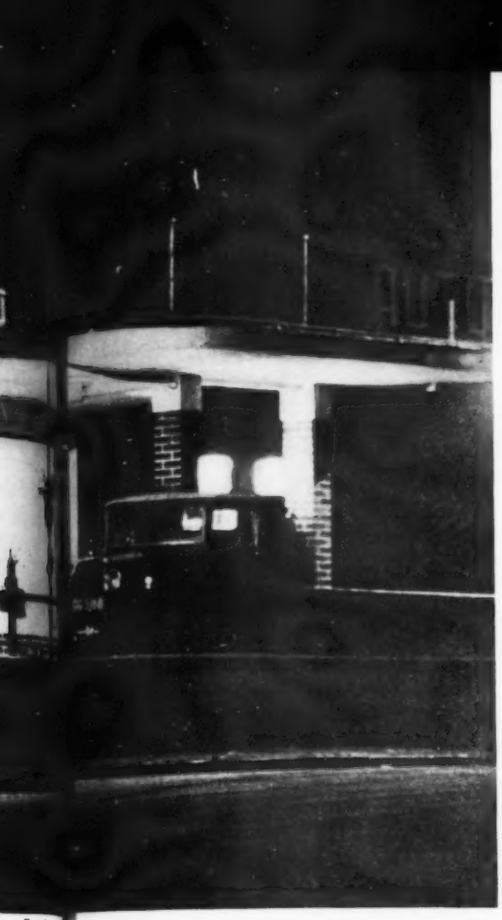
Losses to Petroleum Industry by Resale of Purified or Regenerated Crankcase Drainings May Be Reduced by Fostering Immediate Local Consumption. Actual Cost of Diesel Generator Operating on Crankcase Drainings Compares Favorably With Purchase of Electricity.

USE OF old crankcase drainings on the spot instead of having them reclaimed and sold again for lubricants is an aspect of the oil business which would bear sponsoring by the petroleum industry. Appreciable invasions have been made on the market by re-refined or filtered oils of this nature, and may be considered a serious menace to lubricating oil sales. Even the United States, where fresh oil is always obtainable at low prices, has its oil reclaiming organizations, while in other countries the threat is more severe due to the higher prevailing sales cost. Such plants, where waste lubricants are purified, are to be found in England, France, Germany, Sweden, and probably several other European countries, while the extent to which such organizations have grown, admittedly in localized areas, gives one food for thought.

There are many ills which may prevent a truly healthy lubricating oil sales business in any country. Prominent among these ills is substitution by the retailer of a company's branded product by a cheaper or a reclaimed oil—for dishonesty is rife in any trade—although this has been appreciably diminished due to the introduction and success of tamper-proof packages of metal, glass and cardboard. Such substitution where oils are sold in bulk is both easy and inexpensive, for filters purchased at a nominal sum will permit any garage owner or service station operator to net a reasonable profit at little outlay.

Rapid and continuous developments in the automotive industry have set new standards which demand more carefully refined and higher quality lubricants. The damage done to motors by poorly-made lubricating oils certainly needs no amplification, but despite the recommendations of the automobile manufacturers, price is the determining factor when many customers purchase the products consumed by their cars.

In practically every city of major proportions there may be seen signs advertising lubricating or motor oils for half or



even a quarter the price of nationally advertised brands. Such oils are often either re-refined used motor oil, filtered crankcase drainings, or the partially-refined product known as lube distillate. Frequently reclaimed lubricating oil and distillate are blended. Whichever product it may be, its sale in competition with properly refined new lubricating oil is detrimental to both the oil industry and the best interests of its customers.

It is highly desirable that the traffic in used motor oils should be curbed, otherwise to what good purpose do oil companies lay out large sums of money creating good will for their products? Apart from the actual monetary receipts lost with each case of substitution it should be borne in mind that prestige will probably be also lost—and the customer changes to another brand.

In 1936, the American motoring public bought more than 450,000,000 gal. of lubricating oil. Apart from courtesies and publicity in the form of road maps, free travel bureaus, etc., the American oil industry found it expedient to spend some $25,000,000 in direct advertising through radio, newspapers, magazines and outdoor signboards. Of this, $10,244,463 was spent by six of the large concerns with nation-wide facilities. The dollar for every 18 gal. of motor oil that is spent in creating good will is entirely wasted when inferior products are substituted.

Desirability of such a curb on resale of waste oil is generally recognised, but the creation of an effective means of restraint is not always simple. There seem to be two ways open to the oil companies in America to curtail the reclaimed oil business; either they may collect the used oil from dealers selling their products and thus control its resale, or they may encourage the installation of equipment at retail outlets to consume the waste product. It is with the latter of these two possibilities that this article especially deals.

Inquiry develops that in many cases where population, and therefore motor traffic, is highly concentrated, crankcase drainings are reclaimed in some form or other and used again as motor oil. This is done (1) by major companies, who may or may not employ a collection agency to pick up the drainings from all company-controlled stations and cart them to their refineries where they are re-distilled; (2) by a limited number of concerns who make it their sole or primary business to reclaim sump oil for resale, and whose product on the whole is fairly good; and (3) unscrupulous dealers who collect drainings, filter them and/or mix them with lube distillate or other oil and resell either under the cloak of a branded product or as a premier-grade oil of their own. In some cases good oil has been diluted with waste oil and resold without in any way first refining the drainings.

Where major companies do their own collecting and regenerating from stations under their control the customer may be assured a satisfactory deal, for no important oil concern is going to tarnish its name and good reputation (on which it may spend as much as $3,000,000 in a single year) by turning out an inferior product—second-hand oil—in the guise of a healthy lubricant. In such cases the re-refined oil is invariably blended with a freshly refined but heavier product of good quality and sold for industrial use—not as a motor oil. It may also be sold for use in agricultural machinery and for manufacture of printing ink.

The primary reason for an oil company to reclaim waste sump oil which it collects from its stations is not so much the small additional profit which may ultimately be had, but rather as a precaution against substitution of those same drainings, filtered, by any dishonest retailers.

As has been mentioned, a fairly reliable product is turned out by those companies whose business is reclaiming oil. They are, by the economics of reclamation, limited in their scope, as they can only exist in those concentrated areas where sufficient raw material is readily obtainable. The further the reclaimer must send his collection trucks the higher his overhead, for he must initially pay the dealers from whom he gets his drainings, after which he re-refines the product at about 20 percent loss and must still be able to compete with other low-price oils.

Lubricating oil reclaimers are existent in large cities in the United States, but the intense competition already existing in the trade, because of comparatively low retail prices for even the best grades of motor oil, handicaps them in expanding their operations to any great extent. However, substitution of filtered or reclaimed lubricants for branded products sold in bulk is no doubt more prevalent in that country than in any other.

Drainings are used quite generally, by large industrial concerns whose consumption is great, for rough lubrication work where a coarser product will serve. Such uses include lubrication of conveyor chain

Diesel generating installation at Moon's Kensington garage has reduced cost of electric power from $13.50 to $1.00 per day—one of a chain of large garages, outstanding for its architectural beauty.

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and heavy machinery, or as a skid oil. In some cases the oil is diluted and burned under boilers. The reclaimed product may be used also on crushed rock roads, and as a dust-settling agent. It has been reported that a scheme is proposed to utilize drainings for the manufacture of various other products, but this is in embryo.

From the search in every direction for further possible operating economies by garages and service stations in Great Britain, there has resulted a trend toward self-contained power and lighting plants, independent of the grid (utilities) system that has extended its transmission lines all over the country. This new movement seems likely to spread to a considerable extent in the United Kingdom, particularly as it renders motor spirit vendors independent of public utilities.

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For seven years an oil engine generator operating on crankcase drainings has been saving The North Road Garage, in England, $609.40 annually over cost of current purchased from public utility.

An appreciable proportion of Britain's garages and service stations now produce their own electric power in this manner, but few of them purchase fuel or gas oil to run their engines. A low-priced gravity filter, of which the final medium is a fine sawdust that has been passed through a 20-mesh sieve, is marketed by one of the engine manufacturers. This filter is used to purify oil drainings collected from the sump, handling from seven to 18 gal. per day, according to temperature. Such filtration costs about two shillings (50 cents) per annum, which is the price paid for sawdust. In some cases this filtered oil is used as fuel, in others it is mixed with a lighter oil or filtered sump-flushing oil in the proportion of three gallons of the heavy to one of the light. The twin economies effected by first employing oil engines driving generators to produce electricity and by utilizing waste oil as fuel for the engines are considerable; in one such case electricity costs are reduced to one-thirteenth of the local grid rate.

This new movement might have even greater scope and increased value in the United States. Such a development in utilizing crankcase drainings *in situ* might well be encouraged by the oil industry—principally because it removes the temptation to mix reclaimed oil with branded oil, due to the ease and cheapness with which fuel may be obtained by cleansing dirty sump oil in a filter.

Specific economies already effected in England by installation of oil engines for producing power and electricity are striking. The larger the garage the greater the demand for power and lighting; a typical example of the large installation is that of Moon's Garage, Kensington, London, where the 47 h.p. oil engine installed (driving a 31 kw. generator) produces 144 kw. daily for 4s. ($1.00) as against 54s. ($13.50) at local rates. This cost was based on the use of fuel oil, and not crankcase drainings.

The economies are not limited to large installations—another case is that of the North Road Garage, Great Ponton, Grantham, with a plant of this character. To cope with increased trade a single-cylinder horizontal oil engine, having an extra-heavy flywheel, and giving 10 b.h.p. at 690 r.p.m. was installed; otherwise the set is of standard design and can be satisfactorily run on low-grade fuels. A belt-drive from the engine operates two lathes, a sensitive drill, a mechanical saw, and a two cyld. air-compressor, which charges storage bottles for tire inflation. Directly coupled to the engine is a 6 kw. D.C. generator, having an output of 41.5 amp. at 100-145 volts. For electrical storage there are 56 cells, having a discharge of 10 amp. for 10 hours continous load. This battery meets the demands of overtime jobs, supplies current to the owner's residence, and is metered to the house of a neighbor. It is unnecessary to install such a battery, for, limited to the private use of current, the engine is capable of supplying all the electric power required. Quantity of fuel delivered to the engine is regulated according to load by a governor, so that the unit may be left for long periods with little or no attention. It is seldom imperative to run the engine more than 14 hours daily.

As to the itemized costs of this plant: When first placed in service fuel oil was purchased. Since this initial expense fuel has actually been free, for the waste lubricating oil from the sump is used after being purified in a gravity filter and mixed with filtered washing kerosene, in the proportion of three gallons of the heavy to one of the light, and this is reported to be consumed by the engine as readily as regular fuel oil. Approximately 36 gal. of oil is used annually for lubrication of the engine, at 2s. 8d. per gal., or £4 16s. 0d. ($24.00)

Gravity filter pictured below will purify as much as eighteen gallons of crankcase drainings daily for about fifty cents a year, producing a fuel suitable for use in Diesel generating units.

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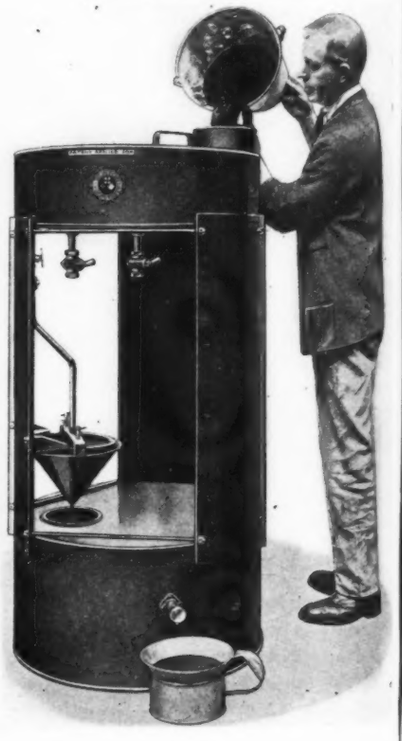


Running attention, fuel preparation, and ordinary maintenance come to 4s. 0d. weekly, or £10 8s. 0d. ($52.00). Decarbonizing thrice yearly amount to £1 2s. 6d. ($5.60). During the first three years five months performance of this engine (11,830 hrs. running time) the only replacements needed were a piston, two sets of rings, and one cylinder liner, which totaled £7 10s. 0d., inclusive of labor, or £2 1s. 0d. ($10.25) per annum.

Writing-off the engine dynamo, generator, filter, switchboard and battery in a seven-year period, the annual depreciation is about £48 9s. 6d. ($242.35). The proportion of the insurance is £1 0s. 0d. ($5.00), while interest on the investment at five percent comes to about £18 7s. 0d. ($91.80).

Records show that the load factor is 66 percent for 11½ hrs., which when the whole load is considered electrical, equals 46 kw. hrs. of electricity per day. The weekly output is 322 kw. hrs., or 16,744 kw. hrs. per annum.

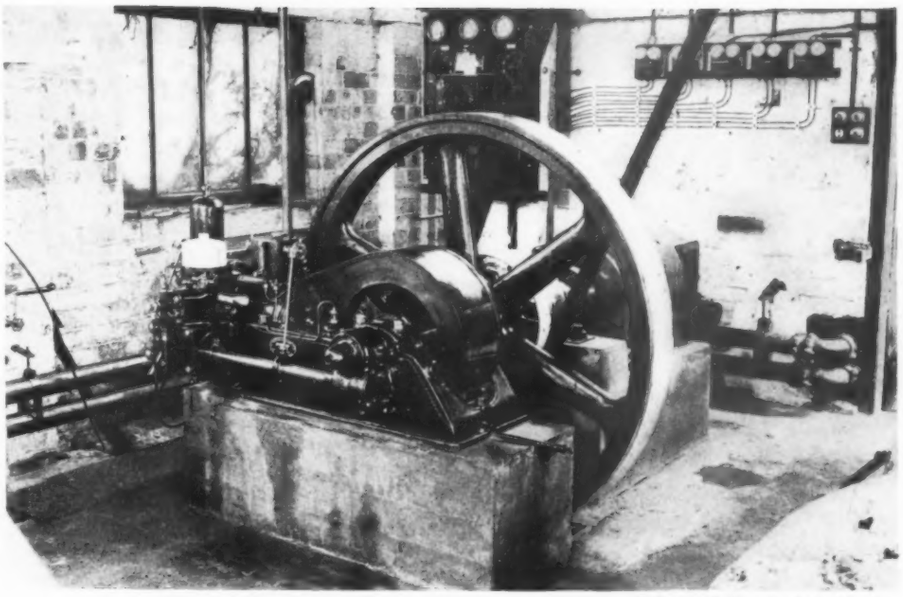
Complete annual expenditure with this Diesel generating plant is £86 4s. 0d. ($431.00), which brings the cost to 1.231d. (2.46c.) per kw. hr. Local grid rates at this point work out to 3.105d. (6.21c.) per kw. hr. for this type of consumer, which would involve a total expenditure of £208 1s. 8d. ($1,040.40) per year for the same quantity of power.

The total saving by the use of a Diesel generator operating on crankcase drainings is, in this typical case, £121 17s. 8d. ($609.40).

A number of Diesel generating sets have been installed in American garages with success. With a comparatively large plant The Boro Gas Shop, New York City, was able to reduce its costs per kilowatt hour to 0.83c. from the 4.94c. formerly paid to the utility company. Naturally, the larger the installation and consumption the greater the savings.

Taking an American service station of average size—say, 15,000 gal. gasoline sales per month—it is possible to work out comparable economies. This station already requires a 2½ h.p. engine for direct-drive power purposes and has in addition an electricity consumption of about 1,000 kw. hrs. per month, which at a local rate of 4.94c. per kw. hr. would amount to $592.80 per annum. Cost of operating the engine would be about $300 per year, or a total cost of nearly $900 for power and lighting. A station of this size would collect about 125 gal. of crankcase drainings each month.

Installation of a 7½ h.p. oil engine coupled to a 3 kw. D.C. generator would not only increase the amount of direct-drive equipment which might be used, but would when operated 16 hrs. per day effect an increase in current available for consumption to 1,426 kw. hrs. per month, without in any way increasing the capital outlay of the owner.



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Diesel generator at The North Road Garage; these engines are designed specifically for use in garages, and are of a rugged character which enables them to operate almost indefinitely on filtered crankcase drainings.

Where local legislation does not prohibit, filtered crankcase drainings could be used as fuel. Filtration would give a recovery of about 90 percent, or 1,350 gal. per annum. An engine of this size operating 16 hrs. a day would consume 2,873 gal. per annum, requiring a purchase of 1,523 gal. yearly of No. 5 fuel oil for blending with the drainings —approximately a fifty-fifty mixture. With a mixture of this nature decarbonizing would probably not be necessary more than once a year, or twice at the outside. Replacements would be few due to the rugged character of this type engine, and only a few minutes attention would be necessary each day.

Using a mixture of filtered crankcase drainings and regular fuel oil, with amortization of the engine and equipment spread over a period of 10 years, it would be possible to effect appreciable economies in both lighting and power. Electricity available for consumption would be increased 50 percent to 17,120 kw. hrs. per annum at a cost of 2.47c per kw. hr. compared with 12,000 kw. hrs. at 4.94c. The annual saving, with increased light and power, would be $170.16.

The advantage of installing small Diesel engines in garages and service stations is only too apparent. Waste motor oil, a bane of the trade, is disposed of in a useful and safe manner; also power and efficient lighting are obtained at less than the cost of utility electricity in many districts. Using this plan over a chain of allied stations, there would not only be a saving in supply cost, but also a reduction in installation costs. Whether the local utility rates were high or low, the garage owner would enjoy an independent source of supply for his various stations.

Will the petroleum industry see fit to foster this movement to use crankcase drainings on the spot for power and light, thus mitigating the evils of substitution? Will it encourage these schemes for burning waste oil under burners and for such heavy industrial lubrication as outlined, or will the unsatisfactory conditions of the past remain through the future?

ANNUAL OPERATING FIGURES FOR DIESEL GENERATOR

Amortization	$290.00
Interest at 5 percent	145.00
Maintenance	88.00
Insurance	5.00
Decarbonizing (twice)	40.00
Replacements	14.99
Fuel	76.15
Lubrication	64.20
Total	$722.00

SUMMARY

Annual Cost of Operating Diesel Generator Compared With Purchase of Electric Power

Total cost of 17,120 kw. hrs. produced by Diesel generator operating on half crankcase drainings and half purchased fuel oil		$722.00
Present cost of 12,000 kw. hrs. purchased from public utility	$592.80	
Present cost of operating 2½ h.p. engine for direct-drive machinery	$300.00	$892.80
Cost of same power as available from Diesel generator (17,120 kw. hrs.) if purchased from public utility	$845.73	
Present cost of operating 2½ h.p. engine for direct-drive machinery	$300.00	$1,145.73
Saving over present power requirements		$170.80
Saving over equal power requirements		$423.73

PRODUCTION DECLINE Anticipated for Peru in 1937

By Julian Greenup, U. S. Commercial Attache, Lima, Peru*

Oil Search Spurred in South America's Third Largest Producing Country — Helium Nationalized. Consumption of Most Refined Petroleum Products Increasing.

PROGRESSIVE recovery of economic conditions in Peru, South America's third largest oil producing country, during 1936 was contributed to in no small way by the increase in production of petroleum in excess of the high rate of previous years, although a slight decline has been evident in 1937. Exports of crude oil were stimulated by a greater international demand in the previous year and the output of both International Petroleum Company and Cia. Petrolera Lobitos rose appreciably, although that of Feustino G. Piaggio Soc. Ltda. Zorritos continued its almost steady decline.

Recent legislation enacted in Peru includes the nationalization of any discoveries of helium, although existence of that element has not yet been revealed in that country. A decree of August 31st, 1937, eserves for the state all helium that may be produced in Peru and prohibits private individuals or companies from exploiting or exporting the gas. Under the decree, the Bureau of Mines and Petroleum is charged with analyzing all gases found in mining deposits now under exploitation. Concessionaires are required to supply the Bureau with all particulars and oil companies must submit semi-annual reports showing the analysis of all gases issuing from their wells.

It appears highly probable that the Peruvian government will reserve to the state exploitation rights over the Zorritos oil lands, in the hope that the development of this area will bring financial benefit to the country. Drilling of the state-owned oilfields was commenced in June, 1936, after preliminary surveys. Petroleum production should be increased if the national reserves in the Lobitos field prove as rich as preliminary drilling seems to promise.

The Peruvian government enacted legislation in order to encourage the exploitation of petroliferous areas in the Amazonian, Trans-Andean, or *montaña* region of the country. The regulations of 1922 contemplated primary conditions of deposits on the coast. It is stated that the presence of petroleum in Puno has been determined by experts, but exploration work in the past has been unsuccessful. The government, in line with its policy of developing all possible sources of industrial fuels, is desirous of intensifying the survey of the Puno oil lands. A commission of engineers has been sent to carry on geological and topographical research work, in order to determine the locations where drilling must be commenced, using the new machinery recently imported.

CRUDE OIL PRODUCTION 1932-1937

Year	Barrels
1932	9,899,265
1933	13,257,318
1934	16,314,381
1935	17,056,555
1936	17,593,069
1937	16,675,000*

* Preliminary estimate

The increased oil search in Peru possibly may be due to falling off in production, for, despite the fact that output has risen steadily during the five years from 1932 through 1936, statistics for the first eight months of this year indicate a decline for 1937. There are three producers: International Petroleum Company operates the La Brea and Parina fields at Talara and Negritos, where there are about 1,800 wells in production; Cia. Petroleros Lobitos (Lobitos Oilfields Ltd.) has about 600 wells producing at Lobitos and Cabo Restin, of which some are 6,000 ft. in depth; Zorritos was the first to be exploited, by Faustino G. Piaggio Soc. Ltda. Zorritos, is 40 miles south of Tumbes, and contains some 40 producing wells. The latter company has its own refinery, and its products are sold in Peru. International Petroleum Company also has a refinery, at Talara, with a daily capacity of 15,000 bbl., where part of the Lobitos crude is refined. Domestic refining in Peru has fallen off to a small extent in the last two or three years.

Peruvian petroleum exports appear to be increasing. During 1936, 10,536,134 bbl. of crude oil valued at $20,814,940 were shipped compared with 9,987,656 bbl. with a value of $18,542,509 during the previous year. Exports of refined products increased to 3,907,169 bbl. valued at $10,475,699 from 3,470,306 bbl. worth $10,424,928 in the corresponding years. Principal purchasers of crude oil from Peru in 1936, in order of importance, were France, Canada, Great Britain, Belgium, Argentina, United States, and Ireland; while of refined petroleum products, Aruba, Brazil, Canada, Chile, Germany and Uruguay were the most important consignees.

Negotiations were under way during 1936 for the restoration of the former treatment accorded Peruvian petroleum imported by Argentina which resulted in the derogation of the surcharge of 50 percent of the import duties on petroleum originating in Peru, applied in December, 1935, while Peru in turn removed a surcharge on Argentine wheat, in accordance with an agreement signed February 3rd, 1937.

Increased industrial activity in the home market and automotive and aero developments in 1936 encouraged the demand for and consumption of refined products, although the total of all products for the year was somewhat lower than that of 1935. Increase in gasoline consumption is believed to be largely due to the abolition of road and bridge tolls throughout the country and to the extension of highways. The domestic demand for this product amounted to 22,800,000 gal., of which 21,800,000 gal. were for motor vehicles and 1,000,000 gal. for aviation purposes, against 19,090,000 gal. and 800,000 gal. of motor and aviation gasoline, respectively, in 1935.

Consumption of kerosene in Peru has been rising steadily during the last five years—this is largely due to the decline in utilization of tractor gas oil, which is continually being replaced as a fuel by the former product. Fuel oil, for both industrial heating and marine bunkering, is steadily increasing in use, as are also grease and asphalt. Lubricating oil, turpentine substitute and petroleum coke, while showing a tendency to increase, are appreciably below the high figure of 1934.

*Courtesy U. S. Department of Commerce.

PERUVIAN STATISTICS

Area: official, 432,184 sq. miles; League of Nations, 482,114 sq. miles. Population: 6,237,000 of which half are aborigines and 600,000 are whites; 14.3 inhabitants per square mile.

Principal industries: nitrates, guano, petroleum, bismuth, copper, gold, silver, vanadium, cotton, wool, alpaca, sugar, wheat, livestock.

Navigable rivers: 3-4,000 miles for vessels of 8-20 ft. draft.

Railways: length 2,810 miles, of which 1,481 miles are under state control; also 94 miles of interurban and 36 miles of urban electric lines.

Roads: length 13,105 miles, of which 60 miles are concrete, 1,140 miles macadamized and 3,146 miles graded earth; during 1937 3,750 miles are being rebuilt or improved and 1,875 miles of new roads are being constructed. Area of 40 sq. miles per mile of road — 1.1 automobiles per mile of road.

Motor vehicles: 10,997 passengers cars; 790 buses; 5,889 trucks; 119 Diesel-powered; total registrations, 17,795. Population per vehicle, 351.

Retail oil prices and taxes (U. S. cents per gallon) as of April, 1937: gasoline, not imported—price at Lima including tax of 7.4, 23.9 in tins, 20.4 in bulk—at Arequipa including tax of 6.6, in tins 26.0; aviation gasoline, not imported—price at Lima including tax of 7.4, 25.0 in tins, 22.4, in bulk—at Arequipa including tax of 6.6, in tins 29.0; premium I, not imported—price at Lima including tax of 7.4, in tins 25.0, in bulk 22.4—at Arequipa including tax of 6.6, in tins 29.0, in bulk 27.0; premium II, not imported—price at Lima including 7.4 tax, in tins 29.0, in bulk 26.0—at Arequipa including tax of 6.6, in tins 33.0, in bulk 31.0; kerosene, not imported—price at Lima in tins, 16.0, in bulk 9.6—at Arequipa in bulk 19.0; imported lubricating oil I—including 20.0 duty and 6 percent ad valorum consular invoice fee (4.4), at Lima and Arequipa 173.0; domestic lubricating oil I—at Lima and Arequipa 89.0; imported lubricating oil II, including 11.0 duty and 6 percent ad valorum consular invoice fee (3.2)—at Lima and Arequipa 87; domestic lubricating oil II—at Lima and Arequipa 74.0; imported lubricating oil III, including 11.0 duty and 6 percent ad valorum consular invoice fee (2.4)—at Lima and Arequipa 66.0; domestic lubricating oil III—at Lima and Arequipa 57.0. Consular invoice fees payable in country of origin.

PRODUCTION OF REFINED PRODUCTS IN PERU 1932-1936

Product	1936	1935	1934	1933	1932
		Barrels			
Gasoline	2,332,869	2,200,082	2,770,162	2,614,322	2,538,181
Kerosene	1,065,016	1,245,214	597,703	531,324	655,646
Turpentine oil	1,410	1,485	1,727	1,101	511
Gas oil	807,430	804,090	543,867	359,306	724
Lubricating oil	32,429	32,162	39,285	31,987	28,090
Fuel oil	1,782,965	1,744,078	2,062,322	1,909,679	1,779,743
Bitumen	28,264	6,790	7,764	3,598	2,033

CONSUMPTION OF REFINED PRODUCTS IN PERU 1932-1936

Product	1936	1935	1934	1933	1932
		Barrels			
Aviation fuel	23,810	19,330	17,652	14,044	10,366
Gasoline	519,191	430,510	354,782	300,902	292,259
Kerosene	130,954	119,469	112,520	101,161	89,935
Turpentine oil	1,374	1,140	2,114	1,204	817
Tractor gas oil	29	924	*	*	*
Lubricating oil	26,204	21,366	66,620	21,127	18,740
Light fuel oil	*	713,400	617,057	542,475	529,904
Heavy fuel oil	*	758,617	690,735	513,578	477,809
Bitumen	28,208	6,770	170	*	63

* Details not available.

IMPORTS OF PETROLEUM INTO PERU IN 1936

Product Tariff Item	Crude Oil No. 901	Gasoline No. 903	Kerosene No. 902	Lube Oil Nos. 905-6	Paraffin Wax No. 909	Asphalt, etc. No. 913
	Barrels	Barrels	Barrels	Barrels	M. Tons	M. Tons
United States	85,625	37,348	2,034	14,845	301.8	1,793.4
Bolivia	....	....	17	....	....	....
Brazil	....	....	11	15	....	....
Colombia	....	21	....	*	....	....
Great Britain	....	....	....	1,896	32.1	251.0
Germany	....	....	....	446	8.2	13.0
Ecuador	....	....	....	15	....	....
Japan	....	....	....	4	....	0.1
Switzerland	....	....	....	3	....	....
France	....	....	....	*	....	....
Guatemala	....	....	....	*	....	....
Canada	....	....	....	392	....	....
Chile	....	....	....	..	110.4	....
Italy	....	....	....	....	30.8	....
British India	....	....	....	....	....	521.2
Java	....	....	....	....	....	178.5
Poland	....	....	....	....	....	129.1
Roumania	....	....	....	....	....	38.9
Malacca	....	....	....	....	....	32.5
Sumatra	....	....	....	....	....	22.7
Total imports	85,625	37,369	2,062	17,617	483.3	2,980.4

* Less than one barrel.

EXPORTS OF PETROLEUM FROM PERU IN 1936

Country of Destination	Crude Oil Barrels	Gasoline Barrels	Kerosene Barrels	Gas Oil Barrels	Lube Oil Barrels	Fuel Oil Barrels	Other Products Bbl. Equivalent
France	4,128,849	....	....	....	....	....	....
Canada	3,651,755	461,400	....	....	....	....	....
Great Britain	2,173,133	....	....	....	....	72,644	....
Argentina	298,522	....	....	....	....	....	....
Belgium	403,249	....	....	....	....	....	....
Norway	64,375	....	....	....	....	....	....
Ireland	136,706	....	....	....	....	....	....
United States	192,648	....	....	....	....	4	....
Italy	93,163	....	....	....	....	....	....
Cuba	89,085	....	....	530,665	....	....	....
Germany	....	269,899	....	62	....	....	....
El Salvador	....	35,367	11,566	379	4,830	....	33
Chile	....	328,795	35,049	....	96	29,105	365
Uruguay	....	131,115	85,028	....	810	....	....
Bolivia	....	44,980	9,143	....	140	36,052	58
Ecuador	....	781	....	....	20	....	1
Honduras	....	11,556	904	....	12	1,139	45
Guatemala	....	1,954	5,361	45	....	870	45
Panama	....	280	1,068	....	....	2	18
Aruba	....	645,670	583,708	....	....	....	....
Brazil	....	89,741	134,095	....	....	....	....
Colombia	....	15,704	....	....	....	....	....
Nicaragua	....	16,925	13,467	....	....	....	....
Canal Zone	....	55,376	....	....	....	8,583	....
Costa Rica	....	....	720	....	....	....	....
Ships' Consumption	22	20	23	....	92	255,666	1
TOTAL EXPORTS	11,231,507	2,109,563	880,132	531,151	6,000	404,065	576

Inspecting an oil seep on the Aguas Clarus property of South American Gulf Oil Company. From left to right, Al Smead and Rex Townsend, of Gulf, with F. C. Ripley, Jr., representative of Continental Emsco.

Foreign Oil Legion

R. T. HASLAM, sales manager of Standard Oil Company of New Jersey, recently had MIGUEL DIVO, Argentine magician, as his guest of honor at a luncheon in the Hotel Pennsylvania, New York. On September 27th Mr. Divo drove a battered Model T Ford through the Holland Tunnel and completed a remarkable journey of 22,000 miles—taking 32 months—that had been started on a dare. The trip proved fatal to two companions, while two others were left in hospitals; he crossed the Andes at 13,000 ft:, was lost without food or water for six days in the Tacoma Desert, hacked a road 375 miles through Colombia with a machete, and lost the car under water in a Costa Rican river for 15 days.

C. J. HANNA, head paleontologist for Tidewater Associated, is completing surveys and mapping the area from Cold Bay to Kanatak, Alaska, about 150 miles southward of Chinitna Bay, where Iniskin Drilling Company is below 500 ft. with its first test well. An exploration well in the Cold Bay district is to be drilled by a concern represented by Tidewater Associated, Union Oil and one of the Standard Oil companies, according to an account published at Anchorage. Mr. Hanna is understood to have determined the location of three anticlines.

ROY LEBKICHER, of California Standard Oil Company Ltd., returned to the United States on the EUROPA during the last week of September after three years residence abroad. During his prolonged absence he has made his headquarters at the company's London office, with periodic trips to the Continent and Bahrein. Mr. Lebkicher is to be in America for about six months on an extended vacation, although he will be also taking the opportunity of keeping in direct touch with his company's head offices.

ANDRE POMPILIU ELIADE, well-known and lively representative of Creditul Minier S. A. R. Pentru Desvoltarea Industriei Miniere in London, was recently married in Paris. His bride was the former Mlle. Madeleine Mahistre.

F. BANKS WARNER, managing director of Cities Service Oil Company, Ltd., arrived in New York from London with his family on board the WESTERNLAND September 14th on a combined business and pleasure trip, expecting to return early November. He has been making periodic trips to the United States since 1920. Mr. Warner told WORLD PETROLEUM that alcohol motor fuel is increasing in popularity very rapidly in Britain, that there is every prospect of even greater increases in consumption, and that his company's alcohol blend is making peaceful penetration of the British market.

J. ROSS CADE, formerly on the drilling staff of Societa Petrolifera Italiana and before that with Lago Petroleum Corporation, is now stationed at Pedranelles, Venezuela, with Standard Oil Company of Venezuela.

H. S. REIZENSTEIN has been appointed contract manager of Westinghouse Electric International Company. A graduate in electrical engineering and business administration at the University of Pittsburgh he entered Westinghouse in 1910. After completing the student course, he was located at East Pittsburgh as a foreign correspondent. In 1913 he became manager of the order department, and in 1915 manager of the price department of Westinghouse International. Mr. Reizenstein served as manager of the advertising department from 1918 until he was made contract manager. As contract manager, he will have charge of the following important related divisions of Westinghouse International: order division, stock control, purchasing, and clerical. Mr. Reizenstein will make his headquarters at 150 Broadway, New York.

H. S. Reizenstein

Dr. Wilhelm Krauss, managing director of Olex Deutsche Benzin - und Petroleum - Gesellschaft M.B.H.—an informal portrait snapped by the editor of World Petroleum while in Berlin on a recent visit.

W. S. FARISH, president of Standard Oil Company (New Jersey), returned to New York September 20th after a series of conferences with the heads of the company's organization in Great Britain. He had already visited Denmark, Norway, Sweden France and Germany, where similar conferences have been held. While abroad Mr. Farish said that he regarded the petroleum outlook as the brightest for a decade. Speaking of the American scene, he stated, "I do not concern myself with politics, except as a citizen and business man. But I think our domestic situation is now getting better. The aftermath of the war left us with significant readjustments to be made in our industrial and social picture. We have been faced with the difficulties to be expected in an attempt to compress into a short period of time a transformation which might normally have needed a quarter of a century. We have, of course, had an unprecedented number of strikes with the consequent loss of production and earning power. In the long run the common sense of a people always reasserts itself to correct extremes, and it is quite apparent that sober second thought is now at work to consolidate the decided advantages of some of our new legislation."

R. C. MCKEE has been appointed assistant manager of the advertising department of Standard Oil Company of Indiana, effective from October 1st, 1937. Work which he has been handling as editor of two of the company's house publications, Standard Service News and Standard Truck Service News, will be taken up by E. D. WHITE, transferred from the South Bend, Ind., office where he has been advertising representative. Mr. McKee succeeds N. H. REED, who will retire on an annuity January 1st, 1938, but will assist meanwhile in the reorganization of the department. Mr. Reed will have been with Standard of Indiana 23 years when he retires. He and a stenographer were the entire advertising department when he joined the company. For many years he was manager. In his earlier years he was a reporter in Nebraska and head of the advertising department of the Santa Fe.

BRITISH OIL IMPORTS

IMPORTS of petroleum into Britain in August were higher than in the corresponding month of 1936. Total receipts for the first eight months were 60,319,000 bbl., an increase of 6.5 percent over the similar period of 1936. The advance has been spread over all but one of the major products. Shipments of lubricating oil declined in August, and the movement of this product during the eight months against the general rising trend is striking in view of the further increase in British industrial activity during the past year. Motor spirit imports increased substantially in August, owing mainly to larger arrivals from Iran. That country has sent 6,672,000 bbl. to the British market during the past eight months, against 4,681,000 bbl. in the same period of last year. Crude oil imports in August declined as against August, 1936, and the total for the year to-date is also slightly lower. Netherlands West Indies easily retains its place as the largest supplier of crude to Britain, with a total this year of 2,705,000 bbl.

British Oil Imports by Products
(Barrels)

	August 1937	8 mos. to Aug. 31 1937	8 mos. to Aug. 31 1936
Motor Spirit	3,579,000	27,481,000	24,586,000
Kerosene	605,000	4,057,000	3,761,000
Gas Oil	537,000	2,757,000	2,181,000
Lubricating Oil	287,000	2,204,000	2,294,000
Fuel Oil	2,279,000	13,438,000	13,194,000
Other sorts	112,000	292,000	283,000
Refined products	7,399,000	50,229,000	46,299,000
Crude oil	1,228,000	10,090,000	10,312,000
Total imports	8,627,000	60,319,000	56,611,000

GULF EXPORT PRICES FOR MAJOR OIL PRODUCTS

	Products	Aug. 18	Aug. 25	Sept. 2	Sept. 9	Sept. 16
		Cents Per Gallon				
GASOLINE:	U. S. Motor	6⅛	6⅛	6⅛	6⅛	6⅛
	64/66-375 E.P.	6⅜	6⅜	6⅜	6⅜	6⅜
	59 Octane and below	6⅛	6	6⅛	6⅛	6⅛
	65 Octane and above	6½	6½	6½	6½	6½
AVIATION GASOLINE:	Gulf Export in cargo lots (Based on last actual transaction)	9	9	9	9	9
KEROSENE:	44 w.w.	5⅛	5⅛	5⅜	5⅜	5⅜
	44/43 w.w.	5	5	5	5	5⅛
	41/43 p.w.	4⅞	4⅞	4⅞	4⅞	5
GAS OIL:	26-30 translucent	4	4	4⅛	4⅛	4⅛
	30 plus translucent	4⅛	4⅛	4¼	4¼	4¼
		Dollars Per Barrel				
FUEL OIL:	Bunker C	1.05	1.05	1.05	1.05	1.05
	Cargo lots	0.95	0.95	0.95	0.94	0.92
	Diesel oil	1.90	1.90	1.90	1.90	1.90
		Cents Per Gallon				
LUBRICATING OIL:	Bright Stock No. 8	28½	28½	27½	27½	27½
	Bright Stock No. 6½	28	28	27	27	27
(New York Export Market)	600 Warren E	25	25	25	25	25
	600 Unfiltered s.r.	21½	21½	21½	21½	21½
	650 Unfiltered s.r.	24	24	24	24	24
	600 Flash s.r.	25	25	25	25	25
	630 Flash s.r.	29	29	29	29	29
	Neutral 200 No. 3	32	32	32	32	32
	Neutral 150 No. 3½	27½	27½	27½	27½	27½
(South Texas Export Market)	Red oil 500 No. 5-6	8½	8½	8½	8½	8½
	750	9¼	9¼	9¼	9¼	9¼
	1200	9¾	9¾	9¾	9¾	9¾
	Pale oil 500	8½	8½	8½	8½	8½
	750	9¼	9¼	9¼	9¼	9¼
	1200	9¾	9¾	9¾	9¾	9¾
		Dollars Per Barrel				
CRUDE OIL:	East Texas delivered at Gulf for export	1.54	1.54	1.54	1.54	1.53½

Prices quoted in preceding issues for Venezuelan, Trinidad and Panuco crude oil are being discontinued as they represent only an occasional spot cargo sale and do not serve as a true indication of the market trend in these countries.

FREIGHT RATES

	Aug. 18		Aug. 25		Sept. 2		Sept. 9		Sept. 16	
	Dirty	Clean	Dirty	Clean	Dirty	Clean	Dirty	Clean	Dirty	Clean
	Shillings Per Ton									
Gulf—U.K./Continent	24/-	27/6	28/6	27/6	25/-	27/6	29/-	26/-	27/-	30/-
California—U.K./Continent	—	—	—	—	no booking		—	—	—	—
Aruba—U.K./Continent	22/-		22/-		22/-		22/-		22/-	
North Atlantic—U.K./Continent	22/-	25/6	22/-	25/6	22/-	25/6	22/-	25/-	22/-	24/-
	Cents Per Barrel									
California—North Atlantic	—	—	—	—	no booking		—	—	—	—
Gulf—North Atlantic	40	40	34	33	34	33	32	34	30	35
Venezuela—North Atlantic	30	—	30	—	30	—	30	—	30	—
Tampico—North Atlantic	40	—	40	—	40	—	40	—	40	—
Curacao—North Atlantic	34	33	34	33	34	33	34	33	34	33

WORLD PETROLEUM ABSTRACTS

Summaries of the Most Important Artieles as Published in the Oil Press of the World Dealing With Technical and Economic Aspects of the Petroleum Industry. Edited by Dr. O. W. Willcox

GEOLOGY OF PETROLEUM

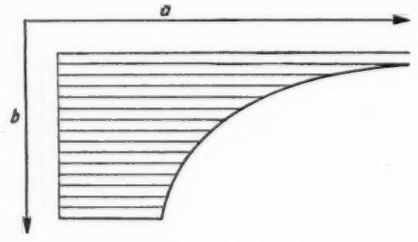
SPECTROGRAPHIC CORRELATION OF OIL WELL WATERS—M. F. Hasler, in GEOPHYSICS, vol. 2 (1937), No. 2, pp. 127-131.

A spectrographic analysis of oil well water brines is described, which allows the detection and measurement of a much larger number of elements than the chemical method usually employed, with a considerable saving of time. This larger number of correlation variables have been analyzed statistically and found to give correlations in many cases where the usual chemical tests were inadequate. It is proposed that the same methods may be applied to core analysis.

NEW PHYSICAL-CHEMICAL VIEWPOINTS ON THE DIAGENESIS OF PETROLEUM—George R. Schultze, before SECOND WORLD PETROLEUM CONGRESS, Paris, June, 1937.

Modern knowledge relating to physical chemistry of hydrocarbons, expecially as regards their thermodynamic stabilities, has advanced so far that at present definite conclusions can be drawn from the composition of a mineral oil as to transformations the original oil may have undergone in the course of various geological periods.

Those hydrocarbons that are thermodynamically the most stable are found in mineral oils, which means that only the most resistant of such compounds are able to survive through long period of time. Correlatively, the most stable hydrocarbons are the oldest. This idea is schematically represented in the accompanying diagram, which pictures the qualitative dependence of the composition of crude oil on its age. The horizontal arrow represents the



specific gravity of the oil base, proceeding from paraffin base to mixed based to naphthene base oils; or more generally, in the sense of increasing value of the ratio C/H in the oil base. The vertical arrow shows the increase of the age of the oil deposit, which more or less closely corresponds to the depth of the oil-bearing formation. Variations observed in crude oils, from young tertiary back to paleozoic, are in accord with thermodynamic considerations.

This point of view renders certain hypotheses on the diagenesis of petroleum deposits more or less untenable. Thus, the hydrogenation theory which has been set up to explain the metamorphosis of the original mother substance is thermodynamically improbable, unless subsequent polymerization processed are assumed. At any rate, the thermodynamic stability of hydrocarbons is now so well recognized that it is a valuable aid in the interpretation of the geology of petroleum deposits.

EVOLUTION OF GULF COAST CRUDE OIL—Donald C. Barton, in BULL. AM. ASSOC. PETROLEUM GEOLOGISTS, vol. 21 (1937) No. 7, pp. 914-946.

Comparison of A.P.I. gravity and percentage content respectively of Miocene, Oligocene, and Eocene Gulf Coast crude oils from depths of 3,000 to 5,000 ft. with the oils of corresponding age from depths of 5,000 to 7,000 ft. shows that A.P.I. gravity of the fractions and percentage content of the lower boiling fractions tend to increase with depth and age. The base of both the lower and the higher boiling fractions tends to change with increasing depth and age from naphthenic to intermediate, and almost to paraffinic. In order of similarity, those age-depth groups of crude oils are arranged; shallower Miocene, shallower Oligocene, deeper Moicene, shallower Eocene, deeper Oligocene, deeper Eocene.

That variation of the Gulf Coast crude is consistent with transformation under the influence of time and some factor or factors proportional to depth below the surface but is inconsistent with alteration under the influence of time and some factor or factors proportional to nearness to the surface. The theory of evolution of the Gulf Coast crude oils from heavy naphthenic ancestral oils under the influence of time and some depth factor or factors therefore still is advocated. The evolution consists in, (a) decrease of the specific gravity of all but the lowest boiling fractions, (b) increase in percentage content of the lower boiling fractions, and (c) transformation of the base from naphthenic toward and almost to paraffinic. Cracking can not be the main reaction in the evolution. Methanation, possibly plus cracking, is regarded as the most plausible explanation of the evolution.

This law of the variation of crude oil is only one of many; and occurrences of one type do not preclude the existence of other types.

STAINING DRILL CUTTINGS FOR CALCITE-DOLOMITE DIFFERENTIATION—W. D. Keller and George E. Moore, in BULL. AM. ASSOC. PETROLEUM GEOLOGISTS, vol. 21 (1937) No. 7, pp. 949-951.

The differentiation of calcite and dolomite in drill cuttings and core is accomplished by the following technique:

Two solutions are used, the first being ferric chloride made up in water to about 2½ percent strength and the second, ammonium sulphide $(NH_4)_2S$ which has been saturated with H_2S. A pan of water or running source is also needed. The rock specimen, either freshly broken or with its surface freshly ground, is first wet with water, then immersed for 5-10 seconds in the $FeCl_3$ solution, and next thoroughly washed and rinsed in water to remove all free $FeCl_3$. Holding it under the faucet for a few seconds serves very well. A second immersion in the $(NH_4)_2S$ solution for about the same length of time, followed by a second water rinse to remove excess chemicals, completes the treatment. The calcite stains black whereas the dolomite is unaffected and retains its original light color. Very minute specks and intergrown angular grains of calcite are accurately, vividly, and distincly marked. No discussion of the reactions involved is given, but probably the effect is caused as follows. Ferric chloride hydrolyzes into ferric hydroxide and hydrochloric acid. The acid formed in hydrolysis equilibrium is weak and therefore attacks calcite but not dolomite. Neutralization at the calcite surface causes deposition of iron hydroxide thereon, and this is stained to black iron sulphide by the ammonium sulphide. About the only precautions necessary are that the specimens be clean (free from grease or any obstructing material) and that account be taken of any ferric chloride which may penetrate and be held interstitial to the grains.

Drill cuttings can be tested by the same technique. A small sample may be held in a wire basket while being immersed, or the cuttings may be covered with the solutions in a beaker and the washing done by decanting with water.

PETROLEUM GEOPHYSICS

DEVELOPMENT OF THE GERMAN NATIONAL GEOPHYSICAL SURVEY—P. Barsch, in OEL UND KOHLE, vol. 13 (1937), No. 25, pp. 641-644.

For obtaining information on a country-wide scale as a basis for exploiting the national mineral resources the German government is executing a comprehensive geophysical survey of its territory.

The primary basis of this survey is given in the first instance by a series of accurate gravity measurements with the pendulum, one such point being established for approximately each 3,000 square miles of territory; the allowable error of these measurements is one mgal. The points thus fixed constitute absolute reference points to which all detailed measurements are referred. Superimposed on this system of pendulum measurements is another network of primary measurements, one per ten square miles, with the gravimeter, which in some cases reach an accuracy of 0.5 mgal. These primary gravimeter measurements serve to disclose broad tectonic features such as old massifs and wide basins, and to some extent special structures like salt domes and anticlines. A similarly planned general magnetic survey with the vertical field balance gives a general idea of the distribution of the plutonic rocks in the deep lying massifs. These regional gravimetric and magnetic surveys are found to dovetail satisfactorily, but the gravimetric measurements are considered to have the greater direct practical value. To insure concordance between pendulum, gravimeter and torsion balance measurements the scales of all instruments are calibrated in a mountainous region where there are differences of several hundred milligals.

With these primary points established, more detailed surveys are made with the torsion balance and by seismic refraction. The torsion balance surveys are on a scale not greater than 1:25,000. Seismic reflection and electrical conductivity surveys are considered less suitable for the purposes of general reconnaisance and are confined to narrow special surveys. As a part of this general survey a

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thorough laboratory study is made of the physical properties of rocks of all horizons from which samples can be obtained. The officials of the geophysical survey co-operate with the national geological survey, and all persons or corporations in possession of geophysical information are required to furnish the same to the government geological survey, and to advise the authorities of plans for future geophysical research in order to avoid duplication of effort. A special liaison is established with drilling operators in the oilfields.

Torsion balance measurements are made at an average rate of 400 stations per block of 100 square kilometers (62 sq. miles). These measurements are tied in with the established gravimeter and pendulum stations, and when 10 or 20 of such blocks are correlated a very exact picture of the gravity features of a region is obtained. Detailed geophysical work is then left to private interests in the oil industry.

Parallel with this general gravity survey is a nation-wide seismic survey, carried out on the basis of two explosion points and 20 measuring points per survey block of 100 sq. kilometers, with profile lines as called for by the geological structure.

Reports from the field crews are turned in fortnightly. They are first digested by geophysicists, who work out the isogams, gravity axes, maxima, minima, etc. The final touches are applied by a geophysically trained geologist. The combined report thus includes all accessible information, and is submitted to the chief of the Reich's drilling program in the form of a folio containing a topographic map, a seismographic map, a structure chart, a summary of all geological information including existing well logs, and finally a chart of the important gradient profiles and their mathematical evaluation. This folio serves as a basis for giving information to the industry.

Atmospheric Potential Gradient Measurements—Lynn G. Howell, in GEOPHYSICS, vol. 2 (1937), No. 2, pp. 161-165.

Relative atmospheric potential gradient measurements were made in the neighborhood of a salt dome. Two sets of measurements were made simultaneously at two different points. Wulf-type electrometers were used with thorium ionium nitrate collectors insulated with sulphur. From the results it is concluded that if there is a change in potential gradient of the atmosphere due to subsurface features this change is very small, and certainly small in comparison to the changes produced in the atmosphere itself. This seems quite reasonable in view of the fact that the ground is for practical purposes a perfect conductor compared to the air, with a few possible exceptions such as dry sand. The change from point to point of radioactivity, humidity, dust, etc., which might influence the gradient probably depends very little on the subsurface and is probably small on the average between points not too far separated.

Interpretation of Geophysical Data—Ludwig W. Blau, in GEOPHYSICS, vol. 2 (1937), No. 2, pp. 95-113.

Geophysical data result from measurements of physical properties. The geophysicist postulates certain possible physical causes of the observed effects. The geologist reasons from observed geologic effects to geologic causes. The difficulties confronting the interpretation of physical effects as reflected in geophysical data in terms of geologic causes are pointed out. The author takes the position that geophysical data must be worked up independently. A competent geophysicist-geologist may combine geophysical and geologic information in the preparation of a report which will then, and only when this procedure is followed, include all present knowledge of the area under investigation.

The requirement that geophysical data be immediately translatable into geologic language and furnish material for drawing geologic contour maps is shown to be incompatible with the nature of geophysical data. Attention is drawn to the changing geophysical scene and to the tendency to use geophysical methods after they have ceased to be adequate for the solution of prospecting problems.

It is suggested that geology can aid geophysics principally through library reconnaissance and advance surface mapping. Geophysics has become a serious competitor of geology in the search for oil, and the geophysic-geological ecotone has advanced steadily into geologic territory.

Continuous Profiling Method of Seismographing for Oil Structures—Sylvain J. Pirson in T. P. NO. 833, L-54, GEOPHYSICAL PROSPECTING, Am. Inst. M. and M. Engrs.

The continuous profiling method of prospecting has been in great favor for the last few years in detailing subsurface structure suitable for oil and gas accumulation. It reduces practically the interpretation and correlation of the seismic reflection records to a mechanical routine with the result that errors are less likely to creep into the final results. Field procedure, computation of the records, and weathering corrections, as well as the correlation procedure, are explained in detail.

DRILLING

Disposal of Salt Water in the Crystal Oilfield (Montcalm Co., Mich.)—G. E. Eddy, in PROGRESS RPT. MICH. GEOL. SURVEY, p. 7.

Because of the danger of contamination of fresh water supplies, the damaging of property of riparian owners along the streams that drain the Crystal area, and because of the danger to fishing and other recreational interests, brine cannot be dumped into the streams. To date, much of the brine has been confined to ponds, but this has proved unsatisfactory because of the porous nature of the soil. Numerous test holes drilled show the soil to be principally sand and gravel. Any water put into ponds readily seeps through the wells and bottom of the pond and mingles with the ground water. Eventually it would find its way to the Grand and Pine rivers and many communities downstream.

Experiments have been made in putting the brine back into the water horizon below the productive zone. Considerable success has been obtained in two wells on the edges of the field, one well taking brine at the rate of 180 bbl. per hour and the other at a much higher rate. In fact, the water-bearing stratum absorbed the brine faster than the pumps could fill the hole. At the present time, this method of brine disposal seems to be the most satisfactory for this area.

Welding of Oil-Well Casing—Louis R. Hodell, in MINING AND METALLURGY, vol. 18 (1937), No. 368, pp. 380-382.

There is now a definite trend toward the use of the welded joint in oil well casing, for the following reasons:

(1) Plain end casing for welding may be bought for 15 percent less than thread-and-coupled casing; some of this is offset by the cost of welding the pipe in the hole but a respectable net profit remains.

(2) A properly welded joint eliminates the leaking in thread-and-coupled joints. This leakage, not noticeable or serious in the past, has become increasingly objectionable because the exhaustion of shallow pools has made for deeper drilling which in turn taps oil reservoirs under greater pressure. Whereas a few years ago pressures of 1,000 lb. per sq. in. were encountered in newly discovered pools, they are now 4,000 lb. and upward. Admittedly, certain thread-and-coupled joints of superior design are available which seem to be leak-proof at these high pressures but they cost more. The welded joint, which is leakproof, is cheaper.

(3) Higher joint efficiencies may be expected from welded joints. The usual thread-and-coupled joint gives a joint efficiency of from 50 to 70 per cent whereas a welded joint may be expected to give from 80 to 100 percent. By efficiency is meant resistance of the joint to tension.

(4) Use of butt-welded joints permits a closer tolerance between inner and outer strings, which may mean that a larger inner string may be run inside an outer string of given diameter; or a smaller outer string may be run to contain a subsequent inner string of a given diameter; and a smaller hole may be drilled to carry either the inner or outer string.

(5) In abandoning wells every effort is made to recover as much pipe as possible from the hole. However, when the pipe has set for many years the various formations settle and pack around it so that there is great friction to overcome in withdrawing the pipe. This is accentuated by the coupling, which extends out from ½ to ¾ in. beyond the stock of the pipe. Butt-joint welds should serve to eliminate much of this drag.

The biggest advance toward successful welding of oil well casing was the introduction of the shielded-arc method, employing the covered electrode. This has a distinct advantage over the acetylene method for this kind of work. The general application of welding to oil field practice has been delayed, first by the scarcity of expert welders who can handle this specialized job, and secondly, because until recently little if any casing has been manufactured for welding; this latter reason is important, for some steels are more weldable than others, and one or two manufacturers have started to produce the more easily worked grade.

A job in which 5,963 ft. of 8⅝ in. 36 lb. casing was welded is described as follows:

Four 300 amp. generators mounted on trucks were used. Four men welded simultaneously, working four hours and resting two until the completion of the job. A rathole about 30 ft. deep, was drilled about seven feet from the well hole. A 40 ft. joint of casing was picked up by the pickup clamps and the catline and lowered into the rathole. A second 40 ft. joint was then picked up and set on top of the first joint. The two were brought into alignment by means of the line-up clamps, after which the joints were tacked through the clamps, then the latter removed, and the joints welded. When the weld was completed, the 80 ft. joint of pipe was picked out of the rathole and lowered into the well hole. Two more singles were welded together into an 80 ft. double and set on top of the 80 ft. already in the hole. Then still another pair of 40 ft. joint was picked up, the first going into the rathole, the second being stabbed on top of the first. From this point on, two welding jobs proceeded at the same time. Two men welded on the joints going in the well hole and two men on those in the rathole, thus doubling up on the work and saving considerable time. Experience indicates that seven-inch welded casing can be run in the over-all time of seven-and-a-half feet per minute. Net saving to the operator in the use of welded joints in place of thread-and-coupled joints appears to vary between five and 12 percent of the cost of the casing.

Automatic Feed and Weight Control—Brad Mills, in OIL WEEKLY, vol. 86 (1937), No. 9, pp. 41-46.

The first application of automatic feed and weight control for rotary drilling in the Gulf Coast has been installed at Hastings. Control consists of a V-8 engine coupled to a self-locking worm gear through a hydraulic transmission. With the drum connected through the low cluth to the line shaft, the entire load of the drill pipe is carried on the worm gear and handled by the V-8 engine.

The system consists of three push switches mounted in a small box on the end of a portable cord. The box is hung on the draw works at the driller's usual position. For manual control the driller uses two of the push buttons. One accelerates the rate of feed and the other retards the speed. By use of these the machine can be regulated either to feed or retrieve the drill pipe at any speed desired, from a few inches

per hour to 120 ft. per hour. Speed may be quickly changed by the driller as conditions change.

Under conditions that require a constant weight, the driller, by manual control, sets the machine feeding at a rate that establishes the desired weight, and simply pushes in a third switch that cuts in the automatic feature. The machine then automatically maintains the weight that was on the bit at the moment the switch was closed.

The two switches used for manual control show a very interesting response. As the operator pushes the lower of the two switches, the controls will begin to operate, and the longer the button is held the faster will become the rate of feeding. When the button is released, the machine will continue to feed at that rate until another change is made. When a slower drilling rate is required, the top button is pushed and held for the time necessary for the control to reach the desired rate of feeding, and if held long enough it will go past the neutral point and start picking up the load. The third switch simply cuts the automatic feature into operation, and when it is desired to change the weight the automatic switch is pulled and the manual switches again are manipulated to find the correct weight.

Rotary Installations Driven by Diesel Engines with Hydraulic Couplings—H. M. Hohman, before second world petroleum congress, Paris, June, 1937.

Remotness and native labor conditions in regions of the Dutch East Indies induced the Royal Dutch-Shell Company to make use of direct Diesel-driven rotary outfits. Objects to be attained were lightness, high speed, and wide speed regulation. Friction clutches were installed. Engines were provided with hydraulic couplings permitting 100 percent slip during a period of 10 to 15 minutes, which is especially desirable for fishing operations. This first design was fairly satisfactory, but left something to be desired on the score of flexibility; the noise from eight or nine chains when drilling was annoying, and the type of friction clutch used on the counter shaft required great physical strength on the part of the operator.

The second outfit was therefore equipped with two engines provided with Vulcan Sinclair couplings with ring valve coupled to the fuel control in such a way that at idling speed (250 r.p.m.) the ring valve is closed and at 350 r.p.m. it is wide open. The lubricating system is used to actuate the ring valve. Countershafts are equipped with disk-type friction clutches and pumps are driven by V-belts. By using a two post three shaft draw works the number of chains used in drilling was reduced to two. The main draw works friction clutch and the reverse gear were operated by oi pressure from a gear pump driven from the end of the countershaft, and the control is arranged so as to regulate them as well as either engine separately or both together from the driller's position.

The outfit is entirely self-contained, including Diesel-driven auxiliary plant for electric current, mud mixing plant complete with pumps, a pump for high pressure water in cementing operations, an electrically driven pumps for water supply. The outfit is distinctly lighter than an equivalent Diesel-electric installation and in operation shows satisfactory economy.

Thixotropy of Muds—M. A. Reid, before second world petroleum congress, Paris, June, 1937.

Thixotropy refers to the property possessed by many suspensions of setting to a jelly when allowed to stand undistrubed; this jelly can be broken down merely by shaking when the suspension reverts to the fluid condition. The change from jelly to liquid and liquid to jelly can be brought about an indifinite number of times.

Thixotropy is met with in drilling muds particularly those to which reagents such as water-glass and sodium tannate have been added. It is probably largely due to the charges carried by particles in suspension and partly also to the size and shape of the particles. It may be that thixotropy is an intermediate stage between perfect stability and complete coagulation of a suspension.

The viscosity of thixotropic mud changes as the jelly forms or is broken down. The viscosity/time relationship associated with thixotropy must not be confused with other changes in viscosity with time.

OIL WELL OPERATION

Acid Treating New Oil Wells—E. A. Newman, in progress rpt. no. 1, mich. geol. survey, pp. 7-8.

An interesting method of drilling in wells has been pioneered by the Gordon Oil Company. Drilling is stopped when the top of the pay is reached. At this point, the well does not usually flow and acid is then pumped in through tubing and is forced out laterally into the pay, rather than downward into the water level. Using this method, more oil per barrel of brine is recovered, and the ultimate encroachment of bottom and edge water is retarded. This practice is more successful than drilling into water and plugging back because in plugging off bottom hole water, it is very difficult to avoid sealing off all or a part of the thin oil pay.

Analysis of Sucker-Rod Down-Time at Oklahoma City—Tom B. Campbell, in oil weekly, vol. 86 (1937), No. 9, pp. 18-24.

The Oklahoma field has the distinction of being the first really deep field to be placed on the pump and thereby gave emphasis to one of the oil producer's major problems, that of sucker-rod down-time due to rod breakage. Causes of such breakage are many and are treated by the author in much detail. Among counter-measures it is recommended to keep working stresses below 30,000 lb. per sq. in. and to use steel of medium rather than high tensile strength, because the former, being more elastic, is less subject to fatigue. Corrosion has never been a major problem in this field, but it has been found that working stresses must be 3,500 lb. less in salt water than in sweet wells.

As regards the future, the author observes that it will be only a matter of time until one-inch rods will be used extensively. Several one-inch and seven-eights inch tapered strings are now being used. It has been difficult to shoulder the one-inch rods snugly but that is being remedied by using larger wrenches. However, as yet one-inch rods are still in the experimental stage. Engineers predict that it will not be long until wells will pump with 1⅛ in., one-inch, ⅞-in. and ¾-in. rods in tapered rod strings operating in tapered strings of three-inch and 2½ in. tubing. Rods will in the future be chosen for individual wells and studies will be concentrated on individual well conditions. The fact that five percent of the wells in Oklahoma City are responsible for 50 percent of the rod down-time proves the necessity of individual well study. Those wells, as a rule, are more important than average wells.

The industry is compelled to go to larger rods. How far they can economically go, and at what rod sizes the dead load will increase the unit stress more than the larger cross section will reduce it are still unanswered questions. No matter what size rods are used one should always remember that the rod string is a very delicate piece of equipment.

NATURAL GAS

Natural Gas in the World Motor Fuel Market—D. E. Buchanan before second world petroleum congress, Paris, June, 1937.

From its beginning the production of natural gasoline has been a conservation measure as well as an adjunct of crude oil production. For a long time in the early history of the oil industry it was a wasted by-product; now it makes no mean contribution to the current supply of motor fuel, as indicated in the accompanying table.

Year	Number Plants	Output, Metric Tons	$ Value At Plant	% U.S. Motor Fuel Prod.
1911	176	18,565	750,000	No data
1916	596	258,740	14,331,148	5
1921	1161	1,184,160	69,626,800	9
1926	1063	3,392,000	129,710,080	10
1931	987	4,578,000	55,677,600	11
1936	859	4,600,000*	65,000,000*	10

*Estimated.

Most of the American natural gasoline that enters the world market comes from the Mid-Continent and Gulf Coast fields. The 18-lb. vapor pressure grade is probably the most popular in cargo markets outside the United States. Typical distillation data of this grade are as follows:

	Low volatile	Medium volatile	High volatile
Gravity (deg. API)	77-81	80-84	84-88
Octane number	65-70	71-74	75-78
Evaporated at 38 deg. C.	5-10%	15-25%	30-40%
Evaporated at 60 deg. C.	30-40%	50-65%	68-80%
Evaporated at 100 deg. C.	70-80%	82-90%	91-96%
End point	185 deg. C.	175 deg. C.	165 deg. C.

A vast amount of research has been directed toward the conversion of the lighter waste hydrocarbons to various synthetic products, such as alcohols, ketones, benzol, toluol, acids, aldehydes, and such condensation products as bakelite. The reaction of these lighter hydrocarbons, at elevated temperatures and pressures, with and without the aid of catalysts is well known, but this field offers slight promise of commercializing any appreciable quantity of these hydrocarbons potentially available, because of the competition of other source materials and the rather limited market, from a volume standpoint, for the finished products.

The first commercial development, of any consequence, of markets for byproducts from the manufacture of natural gasoline was the adaptation of the liquefied petroleum gases to domestic use, such as for space and water heating, cooking, etc., and later for industrial use, such as gas enrichment, heat treating metals, and as motor fuel for specially equipped trucks, buses, locomotives and stationary engines. Here again hope of these markets consuming any worth while percentage of the potential supply does not seem justified.

Polymerization, just now in the initial stages of commercial application, may prove of great benefit to the natural gasoline industry. The rather limited literature available at this time indicates that installations for the polymerization of the saturated hydrocarbons, butane and propane such as are produced as byproducts in the manufacture of natural gasoline, may only be economically feasible where large volumes are available at a central location and such locations are rather few and far between.

Present day yields do not seem to provide sufficient return on plant investment to cover rail transportation of the raw material to the processing plant and leave anything for the manufacturer of the raw material. It is anticipated, however, that, with further perfection of the processes of polymerization, installations will be made in most of the large refineries wherein, particularly the unsaturates in the butane series which are now being incorporated in motor fuel as well as the propane series which are now being burned as fuel, will be polymerized, opening the way for the utilization of additional quantities of natural gasoline, and of higher than today's allowable butane content, in order to replace the volatility now being supplied by the refinery vapor recovery systems.

Evaporation Test of Commercial Butane—H. W. Van der Hoeven, before second world petroleum congress, Paris, June, 1937.

For the analysis of technical butane the N.G.A.A. method of distillation has been used up to now. The author has constructed an apparatus which allows obtaining a much greater accuracy in measuring. This apparatus consists in a graduated conical tube containing 75 cm^3 of butane. This tube, surrounded by an air-bath, is immersed in a water-bath at 75-100 deg. The graph of evaporation is obtained by noting the temperatures corresponding with residual volumes. The graph of evaporation does not show a geater discrepancy than ± 0.2 deg.

TRANSPORTATION

Centrifugaled Cast Iron Pipes for the Petroleum Industry—Pierre Boissou, before second world petroleum congress, Paris, June, 1937.

For several years French iron works have been making cast iron pipes by the centrifugal method for the petroleum industry. These special pipes have the same excellent corrosion resistance of ordinary cast iron, or even better, and because of their characteristic internal structure possess physical and mechanical properties that make them well adapted for the construction of tight, resistant and durable pipelines for oil, even under high pressures.

The pipes may be connected by threaded unions, by male and female screw threads, by welding, by flanges, or by means of flexible and elastic joints, using a special packing ring. Sizes up to six inches can be curved by bending. Several lines constructed with this pipe are in operation in France and Algiers.

Locating PipeLines by Radio—C. M. Brecheisen, before second world petroleum congress, Paris, June, 1937.

The quickest and most economical method of locating a buried pipeline is by using a radio pipeline detector. The detector has many uses both inside and outside of the pipeline field, namely: locating points of injunctions of connected lines, taps, drips, service connections, miscellaneous lines such as may be found around any pump station or refinery, conduit and underground cables, water and gas lines in cities, plumbing and electric wiring inside walls of houses and other buildings, etc. The detector can be used to make inspections on pipelines used for transportation of gasoline and other refined oils in an effort to prevent tapping and subsequent theft of products. The detector set consists of a high frequency transmitter, an ordinary two-stage portable radio receiver, a set of ear phones, and a selective directional loop antenna.

Cost of complete detector set will range from $25.00 to $35.00 depending entirely on the type of the equipment and the quality of the material used in the cabinet. In order to place the radio detector in operation it is only necessary to know the location of the buried pipeline at one point.

REFINING

Vacuum Filtration of Lubricating Oils—J. J. Allison and J. B. Rogerson, in oil & gas jour., vol. 36 (1937), No. 9, pp. 73-75.

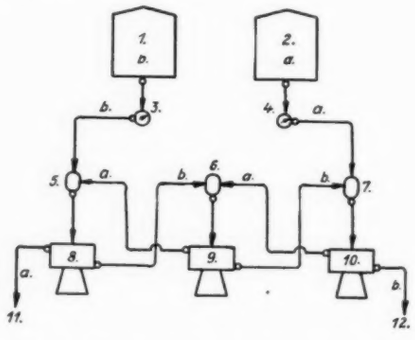
Under the title "Low lubricating stock loss is feature of new Lion vacuum filter" the authors describe what is said to be the first instance of application of an Oliver rotary vacuum filter to the separation of treating clay from lube oils without diluting the oil. In this work there is first built upon the filtering surface a 2-in. layer of diatomaceous earth (Hy-flo cellite). The oil to be clarified is then fed into the filter tank at a constant level. As the drum revolves an advancing knife-edge shaves off the clay layer together with a thin film of the filter aid, which is removed from the filter by means of a screw conveyor. The knife's advance into the coat is at a rate of .0004-in. per revolution, which continues until the coat is about ¼-in. thick when a new coat is put on and the cycle repeated. One cycle lasts 7 days. The installation is said to have a capacity considerably in excess of the usual Sweetland filter, together with a lower labor cost.

The Phenolate Process for Sulphur Removal and Sulphuric Acid Production from Refinery Still Gas—Alfred R. Powell, in natl. petrol. news, vol. 29 (1937), No. 24, pp. 50-58.

Sulphur-bearing gases are bubbled through a cold solution of sodium phenolate, where sodium sulphide is formed and phenol is set free. The solution thus obtained is then boiled, whereupon reverse action occurs, sodium phenolate again being formed and hydrogen sulphide expelled in gaseous form. The regenerated sodium phenolate is then returned to the cycle. This process has been installed at the El Segundo refinery of Standard Oil Company of California to purify 16,600,000 cu. ft. of gas a day; at capacity operation the daily production of hydrogen sulphide gas is 40 tons (98 percent H_2S) which is piped to an acid plant for conversion into sulphuric acid. The recovery of hydrogen sulphide from the gas is 96 percent. Total operating cost is figured at $6.90 per ton of recovered sulphur, which is less than the market price of natural brimstone sulphur.

New Ideas in Practical Solvent Refining, Especially with Phenol—F. Schick, before second world petroleum congress, Paris, June, 1937.

The author presents an apparatus for continuous solvent refining of lubricating oils, using phenol as the solvent. The layout of the extracting system is shown in the accompanying diagram, where in 1 is the oil supply tank, 2 the phenol supply tank; 3 and 4 are meters; 5, 6, 7 are mixing pumps; 8, 9, 10 are centrifugals to run at 8,000 r.p.m., the temperature of the centrifugaled mixture being 70 deg. C.; 11 is the pipe leading to the raffinate column; 12 the pipe leading to the extract column; the letter *a* designates the pipes for oil or raffinate mixture, *b* the pipes for phenol or extract mixture.



The solvent is recovered in a specially designed vacuum column heated by coils through which circulates high pressure steam. No steam is injected into the column, thus avoiding azeotropic phenomena, and the recovered phenol is directly returned to the cycle.

Advantages of this system are simplicity of construction, small space required and the short time necessary for a charge to pass through the system. This high rate of circulation makes it possible to operate with a relatively small quantity of solvent. In order to attain this speed the solvent recovery column is specially designed to effect the separation of phenol and extract at a high rate.

Losses of solvent over weekly periods do not exceed 0.04 to 0.05 percent, figured on weight of oil treated, and where no disturbances in operation occur the loss is under 0.03 percent. No chemical alteration of the phenol has been observed after long use.

Recent Progress in Refinery Acid Recovery—S. F. Spangler, before second world petroleum congress, Paris, June, 1937.

The author first discusses the Hechenbleikner process (Chemico sludge conversion process) for the recovery of sulphuric acid from acid sludge by decomposing the sludge into coke and sulphur dioxide in a rotary furnace; in this process the hot combustion gases are introduced directly into the interior of the furnace and the sulphur dioxide is transformed into sulphuric acid by the contact process.

This process is usable only with certain kinds of acid sludge, especially those originating from the acid refining of white oils. The decomposition products of these sludges contain a very small amount of light hydrocarbons (about 2 percent). The uncondensible hydrocarbons are disposed of by burning in a special furnace.

The majority of acid sludges give rise to decomposition products that are too rich in uncondensible hydrocarbons, so that after purification these gases contain too little sulphur dioxide to be suitable for the contact process. To avoid this disadvantage an attempt has been made to prevent the introduction of combustion gases into the rotary furnace; instead, coke resulting from decomposition of acid sludge is introduced into the furnace and burned at a high temperature. This substitution of coke for gas is possible because the process in general yields an excess of coke. In some cases the acid sludge gives too little coke; when this is the case the coke is in part supplemented by hot sand.

Three factories are being built to utilize this process and will shortly be put in operation.

An Improved PbS Sweetening Process—C. W. Stratford and D. B. Nutt, before second world petroleum congress, Paris, June, 1937.

The doctor treatment with plumbite of soda and all similar refining processes employed up to the present have the following disadvantages: large volume losses, increase of color, decrease of octane number, occasional production of a high copper corrosion index, and a high cost of operation.

Laboratory researches and practical operations pursued through several years according to a definite plan have shown that all these disadvantages may be avoided by introducing some modifications into the classic PbS refining process. The resulting modified process is known as the Stratco PbS refining process; its value has been proved by several years of commercial operations on a large scale.

Reagent employed is a suspension of a preformed, dense PbS in concentrated caustic soda, which has the property of rapid precipitation. The gasoline is intimately contacted with this reagent, which is reactivated during the operation by introduction of a small, measured amount of air. The most important point is to maintain the reagent in a certain condition of chemical equilibrium; that is, a condition in which only a certain known quantity of plumbite and sulphide ions will be present in the solution. This condition is maintained by the continuous introduction of a known quantity of sodium sulphide in solution. Any excess of sodium plumbite which may result from the oxidation of sulphide of lead in alkaline solution is thus precipitated by the sodium sulphide. All excess of plumbite in solution is to be avoided because it modifies the course of the refining process, and has an unfavorable effect on the color of the refined gasoline.

The process thus amounts to a catalytic oxidation under well controlled conditions. Gasoline obtained is sweet and of a good quality.

Analysis of Phases Obtained in an Extraction Process—A. Schaafsma, before second world petroleum congress, Paris, June, 1937.

Three simple methods are compared for determining the concentration of the solvent in the extract and raffinate phases obtained when a mineral oil is extracted by means of a polar solvent. These are: the addition of a solvent, such as alcohol, that does not dissolve the hydrocarbon, followed by centrifugaling; evaporating the solvent and weighing the hydrocarbon; and determination of the dielectric constant of the mixture. The second of these methods is used if the operation is to be followed by a determination of the refractive index of the hydrocarbon, otherwise the third method is employed because it consumes the least time and is to be preferred if no further data on the properties of the oil are required.

Dieletric constant is measured by determining the frequency of an oscillating circuit and comparing the result with a standard frequency. Suitable types of this apparatus are on the market. There is a wide difference between the dieletric constants of hydrocarbon oils and polar solvents such as sulphur

BIG LIFTS

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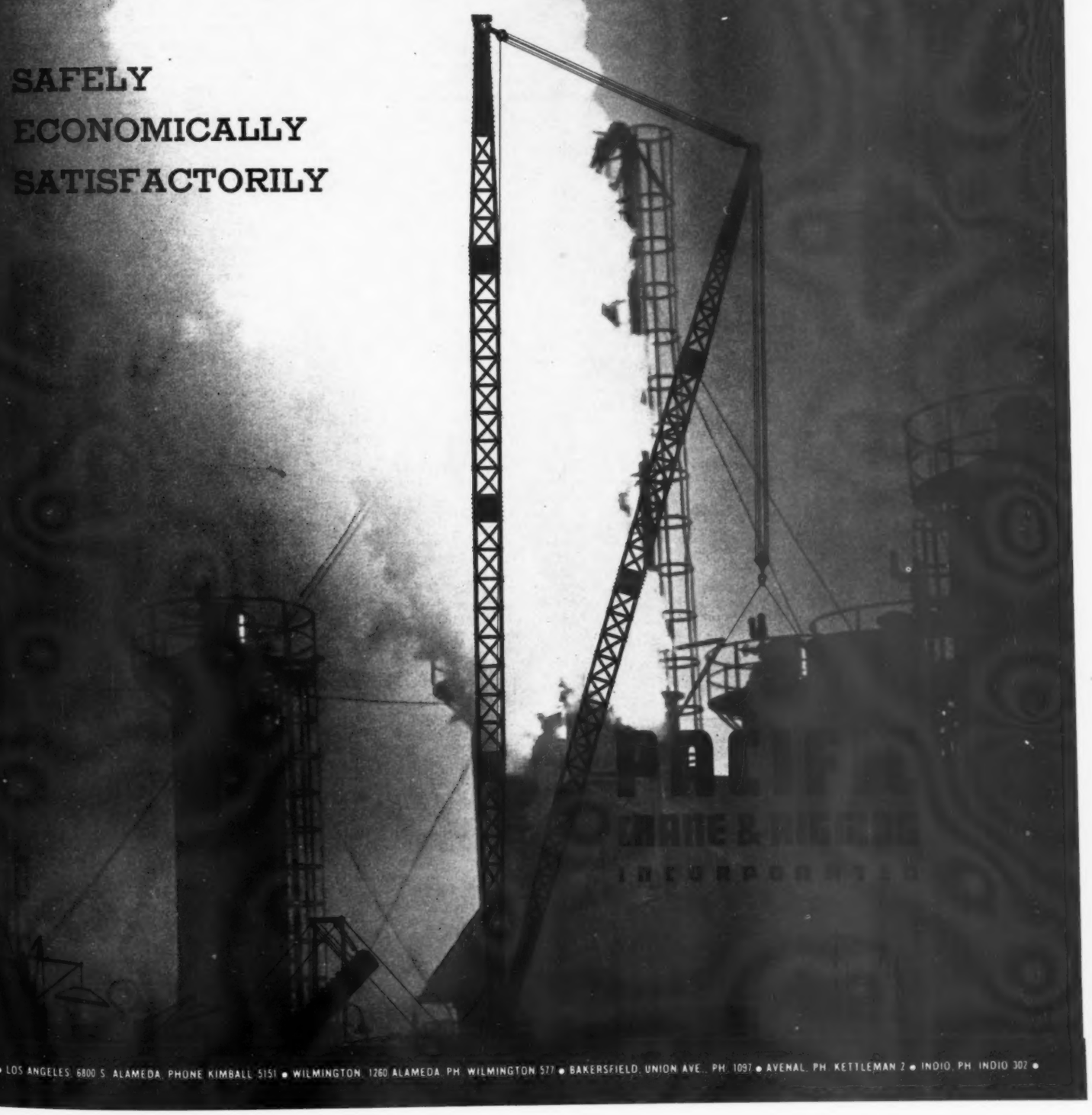

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dioxide, furfurol or nitrobenzene, so that sharply contrasting figures are obtained. Measurements should be made at definite temperatures. A standard curve allows an easy evaluation of the results.

Hydrogenation of Hydrocarbons in the Absence of Catalysts—Andre Leopold, before second world petroleum congress, Paris, June, 1937.

The only difference between hydrogenating hydrocarbons with and without catalysts is the single question of velocity of reaction; the final equilibrium is the same in either case but the time required to reach this equilibrium is short in the one case and long in the other. Hydrogenation without catalysts is of interest chiefly in countries which have at their disposal only shale or schist oil, bitumens or residues derived from imported crude oils. Economical hydrogenation of such materials without catalysts depends on the choice of conditions that will displace the equilibrium as far as possible in the direction of the lighter fractions. Chief among these conditions are initial pressure, final pressure, temperature, ratio of hydrogen to crude material, and composition of the hydrocarbon mixture.

Deodorizing Iraq Crude Oil by Fixing the Hydrogen Sulphide by Means of Soda—Henri Pascal, before second world petroleum congress, Paris, June, 1937.

Owing to the presence in Iraq crude of 0.110 percent of hydrogen sulphide in addition to 1.8 percent of suphur and other sulphur compounds, it was necessary to take measures for reducing the effect of these products, during the interim before the stabilization units were in operation. Toward the end of 1935, the practice was adopted of injecting a seawater soda solution into the crude during pumping operations at Tripoli and Haifa—the H_2S being thereby transformed into Na_2S.

This expedient presented certain difficulties, notably emulsification during shipments, deposition of salt in topping units, and of decomposed mercaptans in cracking equipment.

The problem was solved by breaking the emulsion through heating the crude at a temperature of 194-221 deg. F. and a pressure of 28-43 lb. per sq. in. The period varied according to the water content and the stability of the emulsion. The heavy sodium compounds were eliminated at the same time by injecting 1-2 percent of fresh water with the crude.

Fixed Catalysts in Pressure Hydrogenation—M. Pier, before second world petroleum congress, Paris, June, 1937.

Hydrogenation under pressure with a permanently fixed catalyst in lump or pill form is considerably superior in efficiency and output to pressure hydrogenation with a finely dispersed catalyst; the reason for this is that the lump catalyst displays its effect at a high degree of concentration. Further, the stationary lump catalyst can be used for hydrogenation in either the gaseous or the so-called sump phase, whereas finely dispersed catalysts are now confined to the sump phase and to cases where there is continuous deterioration of the catalysts, which has to be continuously fed in a fresh condition. It is in the direction of fixed catalysts that most progress is now being made in this branch.

Fixed catalysts were first used on a technical scale in hydrogenation-cracking in the gas phase of middle oils originating from a previous hydrogenation in the sump phase at a temperature of about 400 to 500 deg. C. and a pressure of 200 atmos. and higher.

In the range of temperatures below about 400 deg. the cracking effect is reduced, but the volocity of hydrogenation is reduced to a less extent. This still leaves it possible to remove any existing oxygen, nitrogen or sulphur compounds and to hydrogenate the diolefines and even naphthalene. In this case the formation of gas oil and kerosene are promoted at the expense of the heavier oil. In a similar manner it is possible to incorporate more hydrogen in inferior lubricating oils, thus reducing the degree of interdependence between their viscosity and temperature.

Another field of use opened to stationary catalysts is the hydrogenation of heavy products, even such as contain asphaltum. Carbonization tar from lignites, for example, yields highly paraffinous hydrocarbons and a good engine oil; a second hydrogenation reduces these to motor fuels.

The field under consideration is limited only by the possibility of finding catalysts or combinations of catalysts that will meet various conditions and it is along this line that most progress in catalytic hydrogenation is being made. The finely divided catalyst appears to be on the way out. The chief remaining difficulty is to find catalysts that are immune or resistant to poisoning by substances that occur in petroleum products, and expecially in carbonization products of coal; among these sulphur, which occurs in practically all petroleums, is the most formidable, but here the researchers are playing fire against fire, as it were; the tendency is to develop catalysts that are themselves sulphur compounds (MoS, for example).

The Corrosion Problem in French Refineries—Moynard, Moyne and Nocturne, before second world petroleum congress, Paris, June, 1937.

This report is a discussion of corrosion problems studied in the laboratory and plant of the Port Jerome refinery of the Standard Francaise des Petroles. Taking as a basis the corrosion equation set up by U. R. Evans, it is shown how the rapidity of the corrosion varies. This depends on whether the corrosion products remain on the surface of the corroded metal (decrease of rate of corrosion) or are eliminated as they form (erosion).

The influence of the physical state of the corrosive agents is then studied, attention being paid to the vapor phase, solution in unrefined hydrocarbons, solution in water.

In particular, the hydrocarbon phase appears to be corrosive only above approx. 400 deg. F., and as regards corrosion at ordinary temperature, the aqueous phase alone is corrosive. Corrosion rates on the different refinery units at Port Jerome are then indicated, together with the means of overcoming them, as follows:

On the Initial Distillation: Colombian crude gave serious trouble in the condenser and transfer equipment, this being remedied by the use of 18-8 alloy steel, brass, bronze or concrete lining.

On the Cracking Equipment: Trouble caused by the use of Iraq crude with high sulphur content, remedied by the use of 18-8 alloy and 4-6 percent Cr. alloy steel, as well as concrete grunting.

On Chemical Treating equipment: By the use of concrete lining and copper bearing steel.

A last chapter discusses the trouble experienced as a result of running caustic soda treated Iraq crude. This trouble could only be removed by giving up the use of the caustic soda treatment; the elimination of the H_2S was thereafter obtained by treating the crude with NH_3 and finally by pre-distilling it in the vicinity of the oil wells.

Evolutionary Development of Selective Extraction by Phenol—Rene Navarre, before second world petroleum congress, Paris, June, 1937.

During the last four years treating conditions have been greatly modified. Each change has secured a new extension of the process.

First, the lowest possible treating temperature has been used to insure the best yield for a given viscosity index improvement. Besides the reduction in treating losses, there are indications that treating at low temperature will permit higher treatment without overheating effects.

Then, to overcome settling difficulties due to these low temperatures, spent phenol has been cooled down after leaving treating stages and recovered oil recycled with the untreated oil feed. Later, a temperature gradient through the treating stages has been used. Those two practices have confirmed the theories on fractionation in solvent extractions expounded in the First World Petroleum Congress.

The practical results remain far inferior to the theorical extraction results as deduced from the properties of the phenol as a solvent. A change in the separation of the phases—the use of centrifugal machines instead of static settlers—has not shown any effect on that matter. A change in the contact method—the use of treating columns—has improved the practical results.

But there is still much to do to attain theoretical results. The study of the influence of new treating factors as method and time of contact, saturation and equilibrium of phases in each stage will probably result in new great improvements.

At the same time when the conditions of using dry phenol were changed, the use of water dilution has been introduced. Use of wet phenol has allowed satisfactory extension of the extraction process to very low heats for removal of impurities and unsaturated bodies only.

Introduction of water for recycling oil recovery and the use of progressive dilution through the treating stages seems to permit the extension to the higher heats of the benefit of the excellent selectivity and short settling times insured by diluted phenol. Dilution of the spent phenol phase leaving the treating system has also allowed the chemical fractionation of extract in a naphthenic raffinate and a secondary extract. Special uses of the extract recently developed have completed the exploitation of each chemical fraction of the crude lubricating oil.

PETROLEUM CHEMISTRY

Hydrogenation of Some Benzene Hydrocarbons Under High Pressure—M. K Diakova, A V. Lasovoy and I. G. Stefantzeva in jour. inst petroleum technologists, vol. 23 (1937), No. 165, pp. 459-465.

It has been shown that hexamethylbenzene, pentamethylbenzene, 1 : 2 : 4 : 5-tetramethylbeznene, *o*-, *m*-, *p*-xylenes and *n*-propylbenzene can be transformed into corresponding six-membered naphthenes by means of hydrogenation with a nickel catalyst, under pressure of hydrogen from 120 to 230 atm. and at a temperature of 200-240 deg. The reaction is not followed by any splitting-off of the side chains.

New naphthenes: 1 : 2 : 3 : 4 : 5 : 6-hexamethyl-*cckclo*hexane and 1 : 2 : 3 : 4 : 5-pentamethylcyclohexane have been obtained and described.

New constants for some naphthenes have been determined.

Iso-octane Production by Simultaneous Polymerization and Hydrogenation—I. N. Ipatieff and V. I. Komarewski, in ind. eng. chem., vol. 29 (1937), No. 8, p. 958.

Recently a new simultaneous reaction, hydropolymerization, of olefinic hydrocarbons was described. This reaction takes place in the presence of mixed catalysts consisting of a combination of polymerizing and hydrogenating agents. In the presence of such mixed catalysts and hydrogen the simultaneous polymerization and hydrogenation of olefinic hydrocarbons take place, resulting in the formation of hydrogenated polymers; this reaction was therefore called "hydropolymerization." In the study of different catalysts adaptable for this reaction particular attention was given to phosphoric acid, because of its successful use in the polymerization of olefins and the development of the industrial process of catalytic polymerization of cracked gases. The most interesting and important hydrocarbon submitted to hydropolymerization was isobutylene.

By hydropolymerizing isobutylene in the presence of a solid phosphoric acid-nickel oxide-iron catalyst under hydrogen pressure, it was possible to obtain direct a mixture of isomeric octanes.

Isobutylene was obtained by catalytic dehydration of isobutyl alcohol over an alumina catalyst at 350 deg. C. The catalyst was prepared by mixing one-

and-a-half parts of solid phosphoric acid with one part of reduced iron and a half part of nickel oxide. From 108.7 parts of isobutylene there were obtained 100 parts of liquid products, 46 percent of wich was an octane fraction with a boiling point of 100 to 125 deg. C.

Ter Meulen Hydrogenation Method of Determining Sulphur in Gas—G. H. Visser and W. F. Engel, before second world petroleum congress, Paris, June, 1937.

In this method vapor of the substance containing sulphur, mixed with hydrogen, is passed through a tube filled with platinized asbestos, the resulting hydrogen sulphide is absorbed in caustic alkali and determined by a colorimetric method, using a standard plumbite solution. No losses of sulphur occur, the time required is short, only a small quantity of gas is needed, and the operation may be carried out even in refinery atmospheres where the air is contaminated with sulphur fumes. The inconveniences and errors of the combustion method are thus avoided.

Experiments on Synthesis of Naphthenic Acids—J. von Braun, before second world petroleum congress, Paris, June, 1937.

Extensive investigations during the last few years have developed a number of methods which have given some insight into the nature of the naphthenic acids and therefore have contributed to an understanding of petroleum, with which the naphthenic acids are genetically connected.

As starting materials for these syntheses use has been made, aside from adipic acid, of derivatives of geranic acid and cyclopentadiene. The transformations of these compounds and the synthesis of a number of acid types similar to the naphthenic acids and which contain five rings in their structures are extensively described.

Much more difficulty was encountered in the synthesis of the dicyclic acids, and success was attained only in a few cases. The starting materials in this case were the chloromethyl compounds of tetraline and indene, the preparation and transformations of which are described in several cases.

Estimation of Paraffin in Petroleum Products—A. Spack, before second world petroleum congress, Paris, June, 1937.

The methods now in use for estimating paraffin in petroleum products are based on the use of a solvent which dissolves the mineral oil and leaves the paraffin undissolved.

The quantity of paraffin isolated from an oil varies according to the solvent employed; for a given solvent it is difficult to obtain constant results despite all efforts to maintain constant operating conditions; from one experiment to the next, the percentage of paraffin and its melting point varies largely.

These difficulties and uncertainties appear to be removed by the following method: Some of the paraffin is precipitated in a preliminary operation and its melting point is determined. Then a new quantity is precipitated and added to the paraffin first precipitated, and the melting point of the mixture is determined. A third precipitation may be made, the wax thus obtained being added to that obtained by the first two precipitations and the melting point of the combined mass determined. The results, when weights of precipitate and melting points are graphed, are found to lie on a straight line. This is due to the fact that the melting points of paraffins are the higher the lower their solubilities; hence it is easy to establish a standard reference curve that will directly relate melting point to percentage content in an oil, and this linear relation is independent of the temperature; the author worked at different temperatures between 0 deg. and –20 deg. C. using alcohol-ether as the precipitant. Although the quantity of paraffin precipitated by equal quantities of different solvents varies greatly, the same linear relation holds with all solvents (the author used alcohol-ether, methylethylacetone, acetone and ethyl acetate-acetone with identical results). In the case of oils containing asphalt it is advisable to use acetone and heat the solution. The asphalt remains undissolved and may be filtered off; the paraffin may then be separated for melting-point determination at different stages of cooling.

It will be noted that this test does not determine the total quantity of paraffin present in an oil, but only the quantities of paraffin of specific melting points. In refining practice the object is not to get rid of all the soft paraffins, but to reduce their amounts to certain limits. The graphic method here described will be used to establish the content of paraffin of a certain melting point in relation to the quantity to be removed. This renders control of the dewaxing process more exact, and allows of calculating the paraffin balance from either the industrial or the laboratory standpoints.

Methods for Determining the Aging Proclivities of Automotive Lubricating Oils—K. Noack, before second world petroleum congress, Paris, June, 1937.

The existing German specification tests for automotive lubricants do not meet practical necessities because, among other matters, the tendency of these oils to age is neglected.

Before routine testing of this tendency to become altered with age can be established it is necessary to make a comparison of the different methods that have been proposed. As a start in this direction the author examined eight oils of different origins and methods of preparation by six different procedures: the Indiana method, the German precipitation method, the method of the British Air Ministry, the oxidator method of Evers and Schmidt, the Hackford method and the method used by a German industrial works. The characteristic numbers called for by these methods were determined.

The results were not satisfactory, since the different methods did not classify the oils in any consistent way. The reason can only be that the methods rely on discordant concepts. There was no agreement even when the classification was based on viscosity, gravity, neutralization and saponification numbers and asphalt content. This leads to the conclusion that a laboratory method will meet the requirements only when it will produce the same kind and quantity of aging products as are produced in an engine operating under practical conditions.

As such a method the author recommends a procedure which has been worked out at the Chemisch-Technische Reichsanstalt. It is carried out in an evaporation apparatus into which air is sucked over the surface of the oil maintained at a temperature of 250 deg. C. for one hour, the suction pressure being equivalent to the pressure of a water column 40 millimeters high. The oil is then analyzed for total alteration products (petroleum resins and asphalt) by precipitation with normal benzine (Kahlbaum grade for asphalt precipitation); the filtrate is passed over bleaching earth for adsorbing unprecipitated petroleum resins; the adsorbed substances are then extracted by chloroform or benzol alcohol 1:1.

The results obtained on the eight oils in the new test agree very well with the results found in practical operations under the working conditions of the engine. The oils used in this investigation were Diesel oils for trucks, and it is emphasized that the results do not necessarily apply to Diesel oils for airplanes, where conditions and requirements are different. It is now in order to investigate lubricating oils used in connection with such motor fuels as gasoline and liquid gas; whether the new method will apply here remains to be seen.

Graphic Analysis of Hydrocarbon Oils—C. H. Fisher and Abner Eisner, in ind. eng. chem., analyt. ed., vol. 9 (1937), No. 8, pp. 366-370.

The method developed consists in washing the oil successively with sulphuric acid solutions of increasing concentration and determining each time the volume, specific gravity, and refractive index of the unsulfonated oil. The olefin and aromatic contents are then ascertained by plotting volumes of residual oil against the corresponding physical constants. The behavior of the oil and the changes in physical constants during these washings with sulphuric acid are as follows: treatment initially with dilute sulphuric acid and later with acid of higher concentration removes olefins and aromatics progressively, the olefins being first extracted. As the olefins are removed the concentration of aromatics in the residual oil is increased and, as a result, the physical constants (specific gravity and refractive index) observed are higher. The maximum values are reached at the stage of complete removal of olefins (some unreactive olefins may be present) and incipient extraction of aromatics. The volume loss occurring to the point of maximum physical constants is taken as the olefin content.

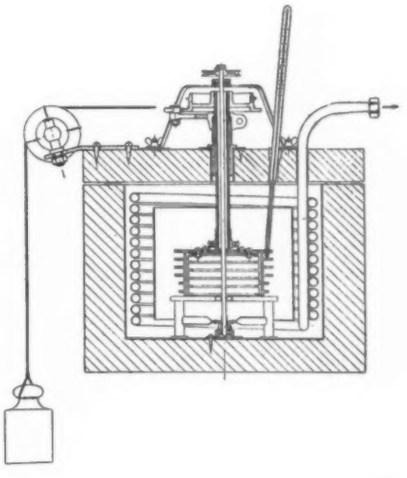
In the second stage of the analysis the sulphuric acid of higher concentration removes the aromatics, causing the physical constants to fall until the removal of the aromatics is complete, when the constants observed are those of the residual naphthenes and paraffins. Treatment with strong sulphuric acid beyond this point has not been studied extensively, but it is known that the volume of oil and physical constants are little changed by further treatment unless the reagent is fuming sulphuric acid. The aromatic content of the original oil is represented by the volume loss occurring between the point of maximum values for physical constants, observed at the beginning of the extraction of aromatics, and the point at which the physical constants become approximately constant because of the complete removal of aromatics. The procedure and its application to neutral oil analysis are clarified by curves obtained in the present work.

This method of examining hydrocarbon oils may overcome some of the difficulties attending the use of previous methods, such as the interaction of olefins and aromatics, extraction of aromatics before olefin removal is complete, etc.

PETROLEUM PHYSICS

Investigations on the Influence of Lubricants on Starting of Motors—K. Schwaiger, before second world petroleum congress, Paris, June, 1937; oel und kohle, vol. 13, p. 715.

One of the main requirements which an automobile engine must meet is that it must be capable of starting up at any temperature. This is generally easily met in warm weather, but in extreme cold the



resistance of the oil used to lubricate the motor may increase to such an extent that considerable force is required to overcome the frictional resistance.

For investigating this property of lubricants use has heretofore been made of the so-called cold room in which full sized engines could be experimented with at temperatures at or below -20 deg. C. After all parts of the engine, together with its oil, have reached the desired temperature, measurements are

made of the electric current necessary to start the motor and to impose on it a certain number of revolutions per minute. From this data it is possible to calculate a reliable figure for the absolute viscosities of various lubricants.

Work with the cold room is time consuming and expensive, although the results are of undoubted exactitude, and so the author has devised a substitute which is illustrated in the accompanying diagram. This apparatus consists essentially of two cylinders, one within the other; the clearance between these cylinders is about 0.05 millimeter, which is practically the same clearance as is allowed in modern high pressure automotive bearings. The opposing surfaces of the two cylinders are wet with the oil under test. The moving parts are enclosed in a space which is cooled by the coils of a sulphur dioxide refrigerator. The outer cylinder is fixed, the inner one is rotated by means of a falling body of constant weight. The time required for the inner cylinder to make a half-turn is noted and furnishes a base from which the exact dynamic viscosity of the oil may be derived in centipoises.

Tests with this machine agree with those made in the cold room. These tests also disclose the fact that the viscosity curves of oils determined according to Dean and Davis, or Ubbelohde and Walther lose practical significance at low temperatures and particularly below the cold points of oils, and so give no reliable indication of the influence of temperature on the ease of starting the engine. On the other hand, the described machine reliably reflects the performance of the oil at all temperatures, even below the cold point.

Viscosimeter with Suspended Level—L. Ubbelohde, in JOUR. INST. PETROLEUM TECHNOLOGISTS, vol. 23 (1937), No. 165, pp. 427-451.

This is an extended review of the author's work which has resulted in a far-reaching improvement of the capillary viscosimeter. The previous form of the instrument employing a suspended plane level is now superceded by a suspended spheric level which finally eliminates any necessity for correction on account of surface tension. There still remained the difficulty of correcting for kinematic energy. This difficulty has now been eliminated by building the correction into the instrument itself so that mere multiplication of the corrected time of discharge by a power of ten (*i.e.* moving the decimal point) is necessary in order to obtain directly the kinematic viscosity in centistokes.

To make the dimensions of the apparatus, especially the capillary, accurate enough, it was necessary to manufacture the capillaries with an accuracy of at least 0.01 mm.

Consideration of all these factors has produced an instrument that is so easy to use and in which all errors are so thoroughly eliminated that in the future it should be scarcely excusable if viscosity data of dubious value are obtained.

Coefficient of Static Friction of Lubricating Oils Measured With the Redgrove Apparatus—D. J. W. Kreulen, in JOUR. INST. PETROLEUM TECHNOLOGISTS, vol. 23 (1937), No. 165, pp. 452-458.

In 1935 E. R. Redgrove introduced a simple apparatus for testing the "oiliness" of lubricating oils. His apparatus consisted of a slider of case-hardened steel supported on three ordinary steel ball bearings contained in a steel cup enclosed in a lagged metal box through which a stream of purified and dried air could be passed. It was mounted on a table which could be tilted by means of a worm and wheel gearing until the angle was attained at which the slider would slip.

In experimenting with Redgrove's apparatus the author at first encountered serious difficulties in obtaining a satisfactory agreement of results. It was finally established that the slider must be finely polished so as to remove all matt surface and scratches. It was also found necessary to eliminate surface tension, which is accomplished by placing slider and balls under the oil to be tested. Thus improved, the results were such that after some days an end-value was reached that proved to be a reproducible constant of the oil. Equilibrium is slowly established; a complete test requires four to five days.

Coefficients of static friction of seven oils were determined. The results appear to confirm the theory of polar compounds, according to which this coefficient depends on certain constituents independent of the base of the oil. Addition of small quantities of polar compounds cause a considerable reduction in the coefficient of friction, and the same applies to addition of an oil with a low coefficient of static friction to an oil with a high coefficient. This is of importance in the compounding of lubricating oils.

ASPHALT AND TAR

Internal Protection of Water Mains by Asphaltic Bitumen Compositions—Pfeiffer and Gobel, before SECOND WORLD PETROLEUM CONGRESS, Paris, June, 1937.

A description is given of the requirements with which internal coating of water main pipes with asphaltic bitumen compositions must comply, and a survey is made of experiments carried out in Amsterdam with regard to the resistance against water currents of some pipes, both with and without an inside coating of bitumen, which had been used for some years in Venezuela..

The pipes not coated proved to contain a large quantity of corrosion products and to have a much greater resistance than the coated pipes on the inner surface of which only a little sediment had settled. The bitumen-lined pipes still had about the same capacity as calculated for freshly lined pipes, whereas the non-coated pipes had lost 50 to 75 percent of their capacity.

Remarks on Ductility Determinations on Asphaltic Bitumens—J. Pfeiffer and R. N. Saal, before SECOND WORLD PETROLEUM CONGRESS, Paris, June, 1937.

The authors present data to show that it must be considered insufficient and often misleading to judge the ductility properties of a bitumen by measuring the ductility according to Dow at one temperature and one rate of strain. It is a fact that of two bitumens having the same penetration, the one with a low ductility at 15 deg. C. 5 cm./min. often has a flatter ductility/temperature curve than one with a higher ductility under the same circumstances. Therefore, it is easily possible that in the case of two asphaltic bitumens of the same penetration but of different ductility (5 cm./min.) at 15 deg. C., the difference in ductility may be reversed at lower temperatures or higher rates. Which of two bitumens will be the most suitable for a given case depends on the possible rates of deformation in practice or in what temperature areas deformations are most dangerous, assuming that the ductility test is a good measure of the cohesion, which itself remains to be proved.

USES OF PETROLEUM

Fuel and Lubrication Problems in Aviation—H. T. Tizzard, in PETROLEUM TIMES, vol. 38 (1937), No. 969, pp. 181-182.

This article quotes from the recently published report of the British Aeronautical Research Committee for 1935/1936. Numerous matters are presented of interest to designers of airplane engines. In the matter of fuel economy the practical advantages of a bi-fuel system are set forth. The idea is that since an aero engine is normally required to deliver its full power for only a few minutes at a time during take-off and initial climb, and for brief bursts of full speed, and if it is supplied for these short periods with a fuel of the highest quality, it should be able to operate for much of its life on a somewhat inferior fuel. It would seem technically uneconomical to use only fuels of the highest quality; and unnecessary since a sufficient supply of fuels of octane number of 100 or over may be a matter of uncertainty for some years. The sub-committee concludes that advantages of a bi-fuel system are likely to outweigh the practical disadvantages of a more elaborate system of installation and control of fuel supply. It seems probable that this conclusion does not apply only to engines specially developed for use with 100 octane fuels. At the R.A.E. a standard Kestrel engine has been run on high-octane fuels at from 50 percent to 70 percent above its normal rated power for short periods totalling some 15 hours without damage or excessive wear. Engine manufacturers have made tests with similar results. Steps are now being taken to fit an aircraft with a bi-fuel system in order to give a practical demonstration of its advantages, and to explore its possible disadvantages more fully.

At present the attention of British aero-engine designers is concentrated on improvement of the petrol engine, but it is felt that there is sufficient prospect of the compression-ignition engine finding a place in aviation, at any rate for long-distance flights, to warrant the pursuit of more active research work. Such an engine would have the advantage of using a safer and possibly cheaper and more available fuel than the specially manufactured fuels now necessary for the modern petrol engine.

PETROLEUM SUBSTITUTES

Large-Scale Technology of Gasoline and Oil Synthesis from Water Gas—F. Martin, before SECOND WORLD PETROLEUM CONGRESS, Paris, June, 1937.

Historical development of the Fischer-Tropsch process is sketched, after which is given an account of the development of the process by the Ruhrchemie A.-G. from 1933 on. Improvements that were introduced during this period include: (1) a considerable lengthening of life of the contact catalyst; (2) an inexpensive, large-scale design of contact chamber and sulphur removal station; (3) a large scale design for recovery of rare metals and metal oxides from spent catalyst; (4) improvement of anti-knock value of Kogasin; and (5) preparation of a cheap synthetic gas from coke, brown coal briquettes and crude brown coal.

Aside from numerous photographic illustrations, the paper contains numerous diagrams and tables of figures showing the quantities, compositions and properties of the raw and finished materials, and the heat economy of the process.

Methanol as Motor Fuel—W. Wilke, before SECOND WORLD PETROLEUM CONGRESS, Paris, June, 1937.

When mixed with other motor fuels the special characteristics of methanol do not appear very prominently; the remarkable properties of this substance are best noticed when it is used by itself. Contrary to the popular impression, the author finds that the efficiency of methanol in comparison with gasoline is as 42 to 38. The anti-knock quality of methanol is outstanding; the octane number, deducted by the mixing method, is 135, which is far above that of benzol or ethyl alcohol. Consequently the compression ratio may go up as high as 1:12 and more. At such compression ratios the thermal efficiency of the Diesel engine is reached.

In one series of experiments with an engine equipped for measuring the average temperatures in the cylinder and in the exhaust pipe, a comparison was made between benzol and methanol, using a compression ratio of 9:5. Efficiency of the latter was seven percent higher than that of the former and the consumption was 12 percent smaller. Average temperature within the cylinder over the whole run was 30 deg. C. higher with methanol and the exhaust temperature was about 36 deg. C. lower. There-

lies the thermo-dynamic superiority of methanol—higher combustion temperatures and lower exhaust temperatures. For the same amount of thermal input methanol does a large amount of work.

As another example a road test with a 3½ ton truck is cited in which gasoline and methanol were compared, using a compression ratio of 1:7. When driven with gasoline the engine consumed 300,000 kcal. per 100 kilometers, whereas with methanol the heat consumption was 230,000 kcal., a difference of 30 percent in favor of methanol; the difference would have been larger had a higher compression ratio been used.

GENERAL

Governmental Assistance in Oil Prospecting in Germany—A. Bentz, in OEL UND KOHLE, vol. 13 (1937), No. 26, pp. 667-669.

Practically the whole of present day German oil production comes from four fields: Nienhagen, Wietze, Eddesse and Oberg, which are all salt dome fields. Many other salt domes are known to exist in the flat North German plain, and some of these have shown signs of oil. Private exploration of these domes has required a considerable capital outlay and up to the present has yielded little or no result.

As is well known, the need of new and larger native supplies of petroleum in Germany is little short of desperate; the government, observing that private capital had about reached the end of its resources, is promoting a large scheme the object of which is to bring to light whatever Germany may yet have in the shape of unexploited oil resources. The primary basis of this program is a thoroughgoing geological and geophysical survey of the country. This survey has been so planned and organized that it constitutes what is probably the most scientific and the most elaborate hunt for oil that the world has yet seen. Besides this systematic primary search for possible oil reservoirs the government has set up a fund in aid of exploratory drilling in new fields indicated by the survey. Subsidies from this fund take the form of interest-bearing loans, which are to be repaid from the gross value of the first oil lifted. In case no oil is found the loan need not be repaid. No loans are granted for drilling in old fields.

Since 1934, when this system of drilling loans was inaugurated, a total of 166,000 meters of hole has been put down; 166 wells have been terminated, 22 are drilling and preparations are underway for starting 15 others. Nine new fields have been discovered, of which five are in Hannover-Braunschweig, one in Schleswig-Holstein and three in the Rhine valley of Bavaria. However, the productivity of these new fields is not yet known, and their further development is being left to private initiative, the government's interest ending with discovery of the field.

Hydrogenation Experiments by the U. S. Government—Albert Orrick, in WORLD PETROLEUM, vol. 8 (1937), No. 7, pp. 42-43.

Experiments on a small scale, designed to explore the possibility of obtaining petroleum from coal have been begun by the Bureau of Mines at its Pittsburgh research station. These experiments have been prompted by the expectation that at some time, possibly not very remote, the present underground supply of petroleum will be exhausted. At present the research is based primarily on the Bergius process and the first objective is to determine which American coals are best adapted for the purpose.

Some Remarks on the A. P. I. Standards—M. Gellar, before SECOND WORLD PETROLEUM CONGRESS, Paris, June, 1937.

While conceding the great value of the standards established by the American Petroleum Institute the author finds certain shortcomings. Some of the standards as set forth in different fasicules appear to be conceived according to different plans. One set of standards (pipe specifications) gives a great number of details regarding materials while another (drilling equipment) does not even mention the word "material." One (sucker rods) uses many figures to give the form of threading and even states tolerances, while another (drilling equipment) neglects to indicate the essential form and dimensions of threading, and completely overlooks the matter of tolerances. And in some cases different fasicules give completely different specifications for the same dimension.

There is still another void that characterizes all the A.P.I. standards. Nothing is said anywhere regarding when a piece should be regarded as unfit for further service, and only in exceptional cases (wire ropes, sucker rods) is there any consideration of surveillance during operation. The lack of indications in this respect is a serious practical inconvenience.

Various objections are stated in regard to acceptance tests on steel. For instance, it is required that one analysis of steel be furnished for each melt, but physical tests are limited to one in 200 or 400 pieces, which is not adequate sampling. A tensile strength test should be made of each pour. Internal imperfections of steels (gaseous inclusions, segregations, etc.) are ignored.

Particular objection is taken to the looseness of the tolerances allowed in the conicity of threads of pipes and unions; these tolerances are allowed to be either positive or negative, with the result that the fit is very bad if the male threads deviate in one direction and the female threads in another. By rewriting its limits of tolerance the "Steaua Romana" has immensely diminished rod failures at the joints. Aside from this, in the A.P.I. Standards (No. 7 B, August, 1936) there is a regrettable dearth of prescriptions regarding the quality of the material to be used for tool joints and rods, pump plungers chains, etc.

In his concluding remarks the author thinks that the A.P.I. would do well to consult a few specialists in the petroleum industries in other countries before a new standard is issued. It would no doubt be well, he thinks, to create regional offices of the A.P.I. Even in the United States conditions affecting the supply and use of equipment are not the same; what is suitable in one district may not be so in another. And he again emphasises the desirability of setting up prescriptions for the surveillance of equipment in use, and especially to indicate when equipment should be scrapped.

Suggested Nomenclature for Fuels, Combustion Phenomena and Engine Fouling in Internal Combustion Motors—G. D. Boerlage and C. A. Bauman, before SECOND WORLD PETROLEUM CONGRESS, Paris, June, 1937.

It would be desirable to have a fixed nomenclature for the phenomena indicated in the title, so that discussions in different languages might be more readily understood. Some technical dictionaries already exist, but the need of extension and correction of these dictionaries is internationally felt. The authors here propose such a nomenclature, which they hope will be accepted as a basis for an international standardization of terms to be worked out by the International Federation of National Standards Association.

BOOKS

Raw Materials in Peace and War, by Eugene Staley. Published 1937 by COUNCIL ON FOREIGN RELATIONS, New York. 326 pages; $3.00.

In this book the author observes that raw materials are the basis of industrial civilization, and he notes that because of their uneven distribution they give rise to conflicts of interest between the "have" and the "have not" countries. Certain countries of Europe are insistently sounding the slogan of "access to raw materials" to convince the rest of the world of the wisdom of a redistribution of the world's resources. In view of this clamor of the "have nots" he proceeds to inquire as to whether these nations have a real grievance, or whether the slogan is merely the pretext of dictators for the furtherance of other designs, and whether there are any feasible measures for the peaceable removal of real and legitimate grievances, if such exist.

After surveying all the facts it is concluded that inequalities in the distribution of raw materials, especially minerals, do exist, and that the international raw material question is an armaments problem. In the present era of political insecurity governments must seek national military power above all else. Self-sufficiency in raw materials that means greater security to one nation means less security to its rival. So long as national power is the real issue behind political demands touching raw materials, no peaceful solution is possible. If nations could feel reasonably safe against war, many raw material problems could doubtless be adjusted by peaceable means.

Assuming that collective security has been established so that nations could regard raw materials in some other light than as armaments, it would remain to concert measures against economic nationalism so that it will not be necessary for nations to have political control over raw materia sources or markets in peacetime, and beyond that to meet specific raw material problems such as those created by monopolies, control schemes, and the like.

Whether or not international raw material problems can be solved peaceably is bound largely to depend on the United States and Great Britain, which in one way or another together control fully three-fourths of the world's production of minerals. These two countries, but more especially the United States, are in a position to make mineral and raw material sanctions effective instruments in support of a collective peace system. Other measures failing, it is concluded that the best way to keep the United States out of war and for preventing war would be for this country to cooperate with other nations for raw material sanctions against an aggressor.

The book contains a large amount of information on the economic structures of the markets for the most important international commodities, with analyses of control schemes and the politics of international investments. Although the author should not be blamed for confining his study to the procurement of raw materials, one feels that he has neglected an opportunity to emphasize that raw materials are merely incidental to the problem of inadequate trade balances. If such nations as Germany or Japan could freely sell the products of their industries there would be no question of their ability to procure raw materials.

Asphalt, a Pocket Reference for Highway Engineers—by Prevost Hubbard and Bernard E. Gray, published 1937 by THE ASPHALT INSTITUTE, U. S. A., for free distribution to highway engineers.

This pocket manual of 237 pages (3⅝" x 5¼") contains 17 chapters packed with information regarding the nature of asphalt and its uses in the construction of highways and asphaltic surfaces in general. The nomenclature of asphalt and its mixtures is given and specifications for highway materials in condensed form. Construction specifications for asphalt surfaces and pavements, the design of asphalt pavements, the equipment of paving plants and the use of modern paving equipment are treated in separate chapters. Chapters are also devoted to non-bituminous bases, to maintenance and resurfacing, to asphalt joint filling and bedding courses, to bridge floors and track construction, tennis courts, sidewalks, playgrounds, and to asphalt revetment and jetty construction. The manual is brought up to date by selected descriptions of asphalt types of surfacing in common use but not yet covered by Asphalt Institute specifications. The text is supplemented by useful tables and an index which facilitates the use of the manual. Various tests used in determining the characteristics of asphaltic materials are explained and illustrated.

WORLD OIL PRODUCTION—Official Figures

All figures furnished direct to WORLD PETROLEUM by governments, except where otherwise specified—Table revised monthly

(Figures in U. S. Barrels—Conversion ratio 7 bbl. = 1 ton)

Country	September 1936	October 1936	November 1936	December 1936	January 1937	February 1937	March 1937	April 1937	May 1937	June 1937	July 1937	Provisional Figures August 1937
United States	90,972,000	95,795,000	91,018,000	97,652,000	98,567,000	93,173,000	106,724,000	104,979,000	110,911,800	105,812,000	110,721,000	108,320,000
Russia[2]	14,936,600	16,118,900	16,019,700	16,412,900	15,476,300	13,247,500	15,273,300	15,749,300	17,409,000	16,250,000[1]	15,200,000[1]	15,200,000
Venezuela	14,626,073	13,888,287	14,307,650	8,452,626	9,888,298	13,583,024	15,584,002	15,192,324	16,032,625	16,820,370	17,036,131	17,902,171
Roumania	5,254,000	5,224,000	4,982,000	5,050,000	4,768,000	4,217,000	4,595,000	4,412,000	4,494,000	4,151,000	4,317,000	4,293,000
Iran[3]	4,487,000	4,704,000	4,620,000	4,963,000	5,250,000	4,417,000	5,866,000	5,768,000	5,789,000	6,153,000	6,573,000	6,600,000
Netherland India	3,731,973	4,059,426	4,139,954	4,190,578	4,267,148	4,011,266	4,405,436	4,348,185	4,553,298	4,464,725	5,208,460	4,888,298
Mexico	3,768,855	3,235,224	3,204,007	4,259,733	4,233,635	3,922,929	4,307,952	4,249,838	3,387,950	3,338,311	3,848,587	2,801,000
Iraq[4]	1,881,782	2,097,564	2,214,954	2,207,954	2,476,698	2,240,119	2,542,883	2,501,772	2,578,401	2,200,254	2,418,101	2,280,572
Colombia[5]	1,575,273	1,600,288	1,537,683	1,641,636	1,668,490	1,617,441	1,622,226	1,660,469	1,678,580	1,724,173	1,682,102	1,592,592
Peru[6]	1,478,482	1,507,433	1,445,605	1,492,023	1,448,545	1,321,989	1,464,979	1,412,094	1,435,796	1,412,678	1,284,588	1,471,913
Argentina	1,323,730	1,306,784	1,356,396	1,356,396	1,355,029	1,237,459	1,317,000[1a]	1,267,000[1]	1,270,000[1]	1,278,000[1]	1,280,000[1]	1,296,000
Trinidad	1,126,420	1,179,611	1,154,093	1,231,365	1,263,456	1,157,408	1,287,097	1,301,260	1,351,198	928,752	1,377,547	1,433,434
Burma[12]	791,217	730,860	778,617	809,218	757,936	756,857	803,327	625,937	690,501	638,874	675,000[1]	650,000
British India[12]								162,699	172,458	181,436	190,000[1]	201,000
Bahrein[7]	422,799	209,086	419,643	619,910	730,064	549,260	799,994	659,557	432,748	684,348	694,000[1]	703,000
Poland	294,000	301,000	294,000	301,000	295,400	273,000	292,600	294,000	294,000	287,000	290,000	293,000
Brunei[8]	257,040	294,070	294,560	322,210	354,480	327,600	357,630	333,410	343,310	320,810	324,310	333,900
Germany	255,556	277,158	265,650	279,545	265,531	233,366	245,007	249,088	247,100	251,482	270,046	282,023
Japan[2]	207,260	200,528	202,385	212,326	219,410	194,037	207,423	198,898	206,544	200,092	204,710	208,000
Ecuador	158,857	168,892	163,870	175,918	180,058	160,675	180,727	181,352	189,658	182,711	186,175	184,780
Sarawak[9]	122,010	127,330	122,920	128,240	125,440	114,380	125,650	119,770	123,480	120,820	131,670	125,700
Canada[10]	135,623	137,004	129,152	139,701	141,078	153,906	175,575	188,014	192,845	209,181	241,737	288,934
Egypt[11]	98,812	102,109	97,755	98,672	99,589	86,842	93,499	89,544	97,146	98,091	99,253	97,888
France[1]	45,000	45,000	45,000	45,000	45,000	45,000	45,000	41,034	45,000	45,000	45,000	45,000
Others[1]	50,500	47,000	42,000	38,000	37,000	40,000	39,000	43,000	45,000	44,000	42,000	36,000
Total	148,000,862	153,356,554	149,155,194	152,178,951	153,913,585	147,281,038	168,355,307	166,027,545	173,930,938	168,364,540	174,340,417	171,529,247

[1]Estimate. [2]Russian Sakhalin included with Russia.—Japanese Sakhalin included with Japan. [3]Anglo-Iranian Oil Company Ltd. figures revised; fuel oil returned to ground has been deducted. [4]Iraq Petroleum Company Ltd. export figures. [5]International Petroleum Company figures. [6]International Petroleum Company and Lobitos Oilfields Ltd. figures. [7]Bahrein Petroleum Company Ltd. figures. [8]British Malayan Petroleum Company Ltd. figures. [9]Sarawak Oilfields Ltd. figures. [10]Includes natural gasoline production. [11]Anglo-Egyptian Oilfields Ltd. figures. [12]Burma and India listed together prior to April 1st, 1937.

Official Crude Oil Production Figures for 1932 to 1937

Country	Daily Average to Aug. 31 1937	Daily Average 1936	Total to Aug. 31 1937	Total 1936	Total 1935	Total 1934	Total 1933	Total 1932
United States	3,455,867	3,001,410	839,775,800	1,098,516,000	996,596,000	908,065,000	905,656,000	785,159,000
Russia	517,306	523,754	125,705,400	191,694,100	176,688,100	168,648,700	149,311,000	149,725,000
Venezuela	502,218	438,844	122,038,945	160,617,095	133,932,614	140,784,804	121,052,354	119,597,337
Roumania	146,259	173,587	35,247,000	63,532,846	61,270,072	61,849,306	53,919,708	53,651,978
Iran	191,012	156,794	46,416,000	57,386,833	52,413,879	52,761,604	49,606,942	45,120,656
Netherland India	148,340	131,043	36,146,816	47,961,744	45,307,913	45,107,828	41,234,498	37,988,913
Mexico	123,828	112,098	30,090,202	41,027,915	40,240,563	38,171,946	34,000,830	32,805,496
Iraq	79,189	76,711	19,238,800	28,076,167	25,733,839	7,214,216	1,018,290	818,300
Colombia*	54,514	51,246	13,246,073	18,756,110	17,617,645	17,340,724	13,157,127	16,834,956
Peru	46,306	48,068	11,252,584	17,593,069	17,056,555	16,314,381	13,257,318	9,899,265
Argentina	42,347	42,235	10,290,488	15,457,960	14,297,025	14,021,901	13,690,556	13,138,747
Trinidad	41,565	36,167	10,100,192	13,237,030	11,671,224	10,894,363	9,561,353	10,126,121
British India and Burma	26,782	25,980	6,506,025	9,508,903	9,218,925	9,200,072	8,743,115	8,817,315
Bahrein	21,617	12,690	5,252,971	4,644,635	1,264,807	285,072	31,977	902
Poland	9,543	10,576	2,319,000	3,871,000	3,902,000	4,012,000	4,174,000	4,220,000
Brunel	9,711	9,008	2,359,900	3,296,938	3,302,905	2,705,350	2,035,656	1,200,026
Germany	8,957	8,503	2,033,643	3,112,200	2,991,800	2,222,500	1,670,200	1,607,900
Japan	6,745	6,568	1,639,114	2,403,072	2,294,878	1,872,837	1,504,412	1,683,439
Ecuador	5,951	5,252	1,446,136	1,922,215*	1,731,785	1,636,619	1,619,902	1,597,641
Sarawak	4,069	4,507	987,910	1,547,882	1,776,593	1,942,591	2,206,815	2,329,733
Canada	7,475	4,110	1,591,270	1,504,287	1,447,204	1,410,895	1,145,333	1,044,412
Egypt	3,135	3,395	761,852	1,242,437	1,235,052	1,502,697	1,627,157	1,855,392
France	1,461	1,562	356,034	534,063	529,664	700,000	786,366	755,146
Others	1,341	1,352	326,000	495,000	559,000	612,000	532,000	503,000
	5,580,569	4,885,460	1,325,086,761	1,787,939,501	1,643,080,060	1,509,277,406	1,431,542,909	1,300,480,675

*Not officially revised

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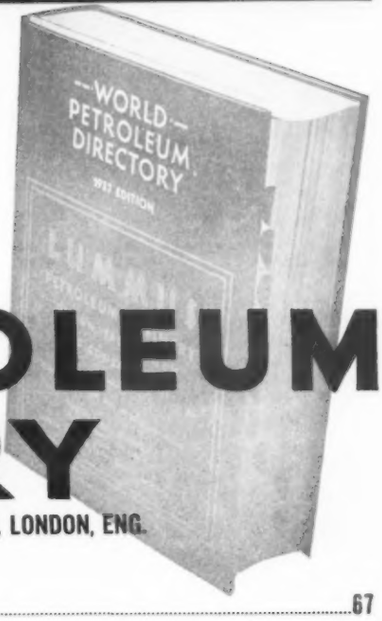

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FIRST large steamship to be built on the Great Lakes since 1930 is the RED CROWN, Standard Oil Company of Indiana's new vessel which was launched with simple ceremonies at Manitowoc, Wisconsin, September 18th, 1937. The RED CROWN slid down the ways broadside, in similar manner to the floating of barges. Mrs. C. J. Barkdull, wife of the executive vice president of Standard Oil Company of Indiana, was sponsor. Edward G. Seubert, president, together with a party of other directors and members of the concern, were present at Manitowoc with their families for the ceremony.

The new vessel was constructed by Manitowoc Shipbuilding Company and has a deadweight capacity of 6,500 tons, carrying about 53,600 bbl. of petroleum products. Her dimensions are: length, 465 ft.; beam, 55 ft.; and depth, 28 ft. Propulsion is by reciprocating steam engines with an output of 2,500 h.p. Outfitting of the ship with oil-fired boilers and other equipment will be completed with a view to putting her into service by the end of the year.

Addition of the RED CROWN—which sets a record as the first large American-built tanker on the Great Lakes in which electric welding has extensively replaced riveting—will increase Standard of Indiana's Great Lakes fleet, engaged in carrying petroleum products to the company's northern bulk distributing points, to five steam tankships, one barge, and a tug.

U. S. S. R.

Official Figures for Soviet Oil Operations

	Crude Production (bbl.)	Daily Average (bbl.)	Run to Stills (bbl.)	Drilling (ft.)
January	15,476,300	499,232	13,839,000	443,310
February	13,247,500	473,035	12,167,400	359,317
March	15,273,300	492,687	13,803,300	540,510
April	15,749,300	524,977	13,813,800	542,390
May	17,409,000	561,581	15,457,400	591,510
June	16,250,000	541,666	14,200,000	520,000
July	15,200,000	490,323	14,200,000	525,000
August	15,200,000	506,667	14,200,000	520,000
Total 8 Months, 1937	124,005,400	510,310	111,680,900	4,042,037
Total 8 Months, 1936	127,755,700	523,589	112,780,000	4,495,319
Total 1936	191,694,100	523,754	173,408,200	6,958,916
Total 1935	176,688,100	497,713	146,705,000	4,858,465
Quota 1937	225,120,000*	617,000	200,000,000	9,240,000
Quota 1936	213,500,000	584,931	175,000,000	7,100,000
Quota 1935	212,310,000	458,042	171,500,000	5,214,000

*Revised from 241,500,000. Crude conversion: seven barrels = one ton.

IZVESTIA, Russian daily, reports friction between Soviet authorities in Sakhalin and the Japanese oil concessionaires. According to an account from Alexandrovsk, Sakhalin, to IZVESTIA, the Japanese operators had decided to build a pipeline from the Katangli field to the coast and started this construction before the Russians had given their consent to the scheme. This, the Soviets protested, as a gross violation of rights granted in the concession. The Russians further contended that the Japanese concessionaires had repeatedly trespassed against many clauses of the concession, and therefore ordered the local authorities to prevent further attempts by the Japanese to continue the pipeline construction.

Subsequently, in the latter part of September, official despatches to Moscow asserted that the Japanese interests in Sakhalin had discharged 4,000 Russian workers and partially shut-down operations, while at almost the same time the Japanese Foreign Office protested to the Soviet government against alleged mistreatment of Japanese workmen in the Russian half of the island. A statement issued from Tokyo declared that 20 such workmen had been arrested, and that Soviet officials had prevented the entry of additional Japanese into the northern, or Russian, half of the island and had interfered with the promised development of the oilfields. It continued: "This unjust attitude has been creating serious unrest among Japanese workmen, and causing an increasing number to apply for permission to return to Japan."

Shortly before these disturbances Sakhalineft, the Soviet oil trust, completed successful drilling of a number of wells in the Ekhabi field, and crude production was increased against previous records. With plan fulfillment at 98 percent, Sakhalin produced a total of 1,225,000 bbl. during the first six months of 1937. About 2,100,000 bbl. were produced in 1936 and 1,750,000 bbl. in 1935. Increased production had also been obtained by the Jap-

The bringing in of the Otto Durbin No. 1 on March 28, 1935—a 3594 barrel gusher—marked the Crystal boom which established Michigan among the leading oil states of the country. Five million cubic feet of gas preceded the gusher, blowing off the control head and spraying oil over the surrounding area. State Police patrolled the roads and the nearby school was closed partly for safety and partly to celebrate the good news.

Michigan has every right to celebrate its outstanding progress as an oil producing state. Moreover, out of Michigan came the Dowell method of *Inhibited* Acidizing which has done more to boost production in the areas served than any development since the perfection of the rotary drill.

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OIL AND GAS WELL CHEMICAL SERVICE

anese North Sakhalin Oil Company, whose output during the first half of 1937 was reported at 980,000 bbl. against a quota of 1,834,000 bbl. for the year.

Distribution of Russian oil in Finland has been taken over by Suoma Lainen O/Y Alfred Olsen and Company, a subsidiary of Alfred Olsen Company of Copenhagen, Denmark, which recently acquired Russian oil distribution facilities in Scandinavia.

No material changes were effected in Soviet crude oil production during August, and the general situation is far from satisfactory. Baku fields, which had shown statistical improvements from 97 to 102 percent of plan during May and June, fell

Plan Fulfillment by Russian Oilfields in August

Field	Percent
Baku	92-93
Grozni	70-72
Maikop	93-96
Bashkiria	52-63
Emba	59-64
Voroshilov	50-59
Kalinin	67-78
Sakhalin	94-99
Turcomaneft	77-91

behind again in July and August, and plan fulfillment for all Baku fields ranged between 92 and 93 percent in the latter month. Kaganovitch still maintains plan fulfillment of 100 percent, but others range quite low—Artema between 81 and 82, Aliati from 50 to 78, and Kergez between 42 and 46. Operations at the Grozni, Maikop and Emba groups were in a slightly better statistical position than in July. During the first eight months of 1937 Soviet fields were not only behind plan but were also below the corresponding showing for the previous year.

One might go so far as to say that it would take a miracle to effect improvements sufficiently great to offset the arrears in production already incurred by the Russian oilfield groups. The best period for drilling new wells and maintaining existing producers is practically over—weather conditions in the late autumn and winter make most roads impassible and practically cut off many fields from outside communication and supplies. Statistics indicate that 1937 will not compare any too favorably with 1936, and Soviet government key men appear to be alarmed at the probable outcome.

PRAVDA, for August 9th, states in an editorial that: "The oil industry is among the major branches of Soviet National Economy which are lagging behind operating quotas. Summing up the situation we find that the industry is barely reaching the level of last year, and individual fields are in an especially bad position.

"Oil operators have no convincing alibi to vindicate the exclusively-poor operation of the oil industry. Soviet petroleum resources are intact and are equal to about half the world's reserves. Soviet oil operators have no cause to complain of lack of equipment. Commissions of Soviet Heavy Industries returning from visits to the United States have ridiculed the opinion that American producers are getting better results due to use of better equipment or equipment unknown to Russian operators. The Russian oil industry has at its disposal similar types of equipment to that used in American oilfield practice. Shortcomings are to be found not in supply but in organization of the industry. Utilization of manpower is inefficient. The party and government have repeatedly warned oil operators to set their house in order, and each time the latter have promised to do so; they have called conferences and have discussed matters, but have done nothing else.

"Following the All Union Conference of Oil Operators in March, Baku operators were able to show practical improvements. Daily average crude output grew to 441,000 bbl.—an all-time record for the field. The operators proved unable to hold this position and after a short time the curve of production went down.

"Glavneft is the head organization of the Soviet oil industry, directing all joint operations. No oil trust feels that it is being helped by the guiding hand of Galvneft. Headed by M. V. Barinov, it is one of those Soviet institutions which has never tried to unify activities or effect a practical policy for all the oil trusts in its embrace.

"Most criminal characteristic of Glavneft is its attitude toward Emba. According to recent estimates (Seventeenth International Geological Congress) Emba's oil deposits ready for exploitation amount to 214,200,000 bbl., but for the last six years Emba has never fulfilled its producing quota in spite of the fact that these plans were always below objective possibilities. During the first seven months of 1937 the field's output came to 42 percent of plan and the Orsk refineries, built exclusively to refine Emba oil, are undercharged. What has Glavneft done to mitigate the situation? What has it done to develop this prolific oil region? Emba is not a recent discovery, but the most important region in the formation of the second oil base in the east, of which Joseph Stalin himself said: 'Without this new oil base our transport and most important industries will find themselves in the position of a deepsea craft plying in shallow waters.'

"When, in 1936, the head of Heavy Industries demanded a drilling speed of about 2,000 ft. per table month, it was claimed to be impossible. Stakhanovites showed by the end of the year that Russian drillers with Soviet equipment had reached American standards of speed. Why are drilling showings down? What are the causes of such arrears? Perhaps the reason is that the heads of the fields are unable to popularize Stakhanov tempos in drilling.

"Neither at Baku nor Grozni have any party officials taken a proper attitude in the 'fight for oil' and they have tolerated alien elements in the oilfields. What has Glavneft done to mitigate the situation in regard to small producers? Is Glavneft aware that at Baku and other Soviet fields the number of wells operating is below the corresponding figure for 1936? The officials of the oil industry together with the heads of Glavneft have done little to liquidate the results of wrecking operations. They are short-sighted and seem to be politically unworried.

"The Soviet petroleum industry with its formidable riches ought not to be lagging. It must become the most progressive link of Soviet National Economy. While capitalistic countries think of oil in terms of conquest of foreign territories and colonial robbery, Soviet oil men have to think only of civilized exploitation, adequate organiza-

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tion of operations and labor, and mastering of technique. Every operator, from the humblest worker up to the highest official, must be aware of his duties to the country and the people. He must realize that he is employed by the government and that upon the tempo of his operations depends the progress of Soviet National Economy."

Soviet Oil Exports

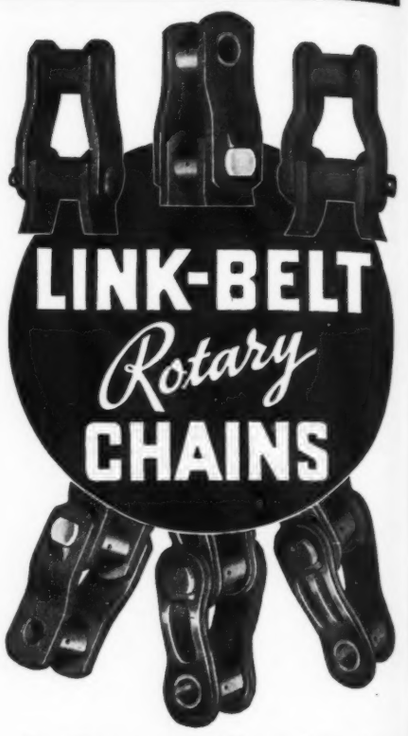
Product	January-June 1937	
	Tons	Rubles
Crude oil	47,864	1,751,000
Gasoline	219,124	22,248,000
Kerosene	143,332	11,139,000
Lubricating oil	99,912	12,285,000
Diesel oil	5,279	179,000
Gas oil	201,209	11,848,000
Fuel oil	330,119	12,135,000
Asphalt and others	2,281	192,000
Paraffin	4,039	1,730,000
Total 6 months	1,049,120	71,777,000

Imports of gasoline into U. S. S. R. from U. S. A. during the first six months of 1937 were 46,438 tons valued at 5,396,000 Rbl.

Criticism of Barinov by PRAVDA may have the same bearing as the similar denunciation aimed at Slutzki shortly before his downfall and which was mentioned in these notes. ZA INDUSTRIALZATIU, number 165, makes similar comments with regard to the recent discovery of oil at Sizran, where there are four wells producing about 1,000 bbl. daily and two nearing completion. The wells will have to shut in until adequate storage facilities are erected. It says: "Construction of the pipeline from Sizran to Batraki railway station illustrates the methods of Glavneft toward the development of a promising oilfield. The heads of Glavneft, particularly M. Barinov, like to point out that Russia is behind America in prospecting new oil regions. This is true, but it is not enough to draw attention to this failing—Glavneft, and M. Barinov as its chief, should have indicated a way to overcome the disparity. Development of Sizran oil shows once more how far words are from actions with Glavneft and its head, M. Barinov. Sizran must be developed and Glavneft, Vostokneft, and the oilfield management will have to awaken to the necessity of changing methods of operation."

The Soviet government continues its grand clean-up campaign. The Commissariat for Heavy Industries has been divided into two divisions, one for machine production and the other for metallurgy, mining, and the chemical and oil industries. The former will be headed by V. Mezhlauk, recently appointed successor to the late commissar Ordzonikidze. The latter will be under Lazar Kaganovitch, who probably more than anyone else, except Stalin, speeded up farm production and transport. He has already turned his attention to the coal industry, discharged a number of officials and introduced several reforms. Now that the oil industry is under his supervision changes are to be expected.

J. WEGRIN



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H. Arnold
Jacobsen

EDITORIAL

PROGRESS IN THE REFINING INDUSTRY

REMARKABLE as has been the progress of the oil refining art in the past thirty years, the problems remaining before the industry for solution today are more numerous and varied than at the beginning of this period. This seeming paradox is simply enough explained. The demand put upon the industry by new types of engines and new applications of liquid fuel have forced the development of products capable of yielding greater power, meeting higher pressures, and generally giving higher performance than was required, or would have been possible, in that earlier day.

The trend of the times is to magnify the role of the chemist and the importance of chemical research in the march of petroleum progress, and the more closely the chemical engineers examine a drop of oil, the more fully they dissect it and study its constituents, the greater the possibilities they see in it, both in the way of better accomplishment in the tasks it is now performing and in the formation of new and useful products through new combinations.

The greatest single forward step in the history of petroleum refining was the development of cracking. Though constant improvement has been made in the methods and equipment employed, the knowledge available regarding this subject is by no means complete. A great amount of research is being devoted to cracking methods and results. Undoubtedly this will lead to the recovery of larger quantities of the more valuable fractions from each barrel of crude and to the suppression of undesirable wastes. Many petroleum chemists expect to see great changes in this field within the next few years, particularly through the application of catalysis.

But cracking leaves something—in fact, a great deal—to be desired. Cracking meant and still means splitting into fragments. It represented a gain in that, through the process of smashing the large molecules of crude oil into smaller ones, on the whole there was obtained a greater proportion of products that could be put to profitable use as motor fuel. But there was much waste; and even the cracked gasoline had its defects. Progress was not left standing at that point. On came a whole drove of new departures—really amounting to new sciences, such as the science of inhibition which conquered the gumming evil by protecting the olefines of cracked gasoline, and the science of solvent extraction which transformed inferior lubricating fractions into the best of their kind. Then came hydrogenation to win new values from nearly hopeless residues, and with it came polymerization to create spectacular new products out of gases and other inferior materials and thus to present the aviators and perhaps eventually even ordinary motorists with iso-octane blends.

At the moment the refining industry is consolidating these various gains. While preparing to push on into new fields it still has to take care of its large every-day job of providing the automobilist with oils that will meet the current specifications of manufacturers of automotive vehicles. It has to give increasing attention to the rapidly expanding consumption of fuel oils for domestic use, the specifications for which are becoming more and more exacting but which gives promise of a much larger future market; and it still has before it the problem of perfecting its Diesel fuels to the point where a much greater use of the economical Diesel engine will be a matter of course.

The major items of refining progress above enumerated are now more or less well behind us. What will the future bring? What will remain for research departments and inventors to do when all gasolines are 100 plus octane, when all lubricating oils have flat viscosity curves, when even the best minds are unable to write closer specifications for Diesel fuels or domestic fuel oil, or even for asphalt and bitumen, when the technologists have constructed the perfect still that will easily and cheaply cut a crude oil or a cracked product into just the right fractions?

We may be reasonably sure that inventors in undiminished numbers will still tread the path to the patent office and that the evolution of new oil refining processes will still continue for a long time to come. Just what the new inventions and processes will be we cannot say, but we can point to one road along which the oil refining industry will press—a road which it already has entered on. This is the conversion of petroleum into basic organic chemicals that are capable of an infinite variety of uses in unpredictable volumes. There is here an apparently boundless future for oil, and a field for research and technology that will provide ample scope for engineering and business talent.

CHEMICAL ENGINEERING Processes Mark Refinery Technology Trend

Two years ago World Petroleum published an article in which the technical problems confronting the refining industry were discussed by members of the research organization of one of the most successful and progressive international oil companies. It attracted widespread attention and was hailed as one of the most interesting articles of the year. Rereading it a few months ago the Editor was more strongly impressed by it than on its original appearance because the developments forecast by the authors in 1935 were exactly those which have had greatest significance in the progress of the industry since that time. We consider ourselves fortunate, therefore, in having persuaded the same authors to make a similar wide range foreview of trends in technological development as they exist today. It is a forward looking article that every reader will find interesting.

Photo by Robert Yarnall Richie—Courtesy The Texas Corp.

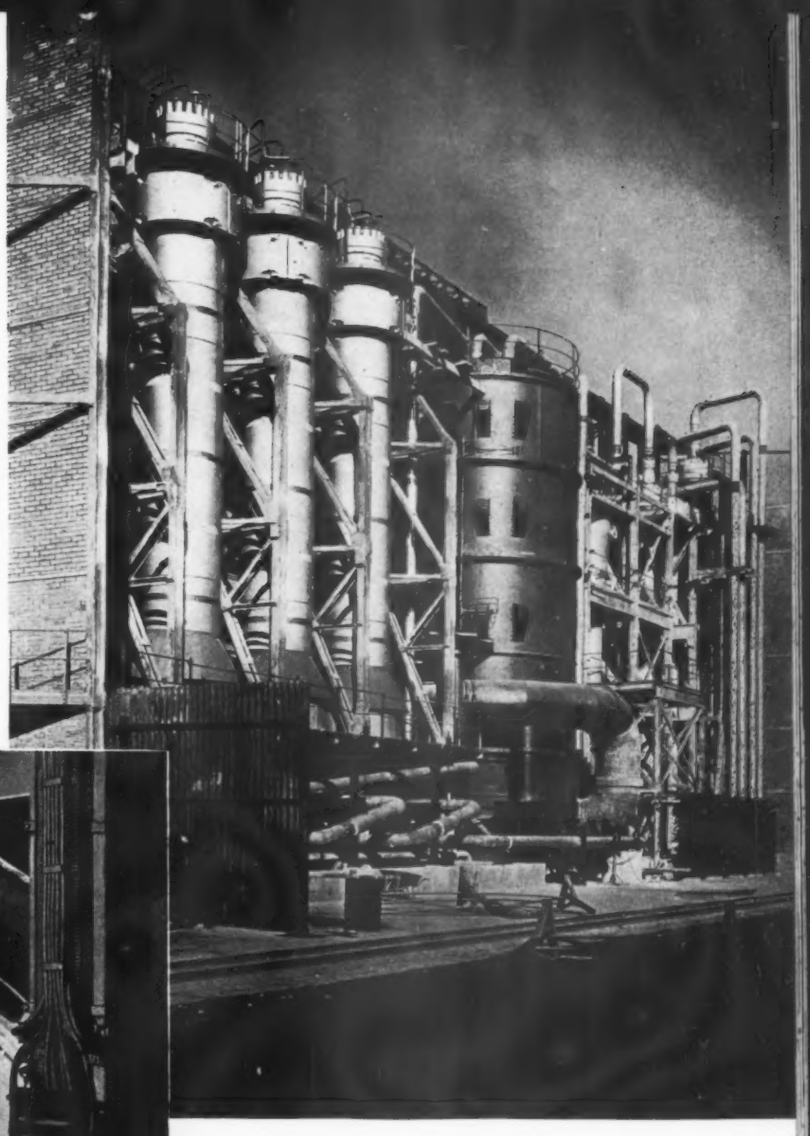
THE TREND in refinery technology is toward the utilization of chemical engineering processes new to the industry and toward more scientific control of established processes continued in use. In the production of gasoline in the recent past, cracking and reforming followed by acid treating, rerunning and doctor sweetening were the only available means of changing the chemical characteristics of available stocks, and these operations were expensive particularly where drastic treatment was required. Refiners today find it economical to utilize the new tools of polymerization, hydrogenation, and chemical inhibitors in conjunction with processes now available, to assist in the production of motor fuels chemically as well as physically best suited for their application. Synthetic processes for the production of hydrocarbons of different structures have begun to be adopted in the industry.

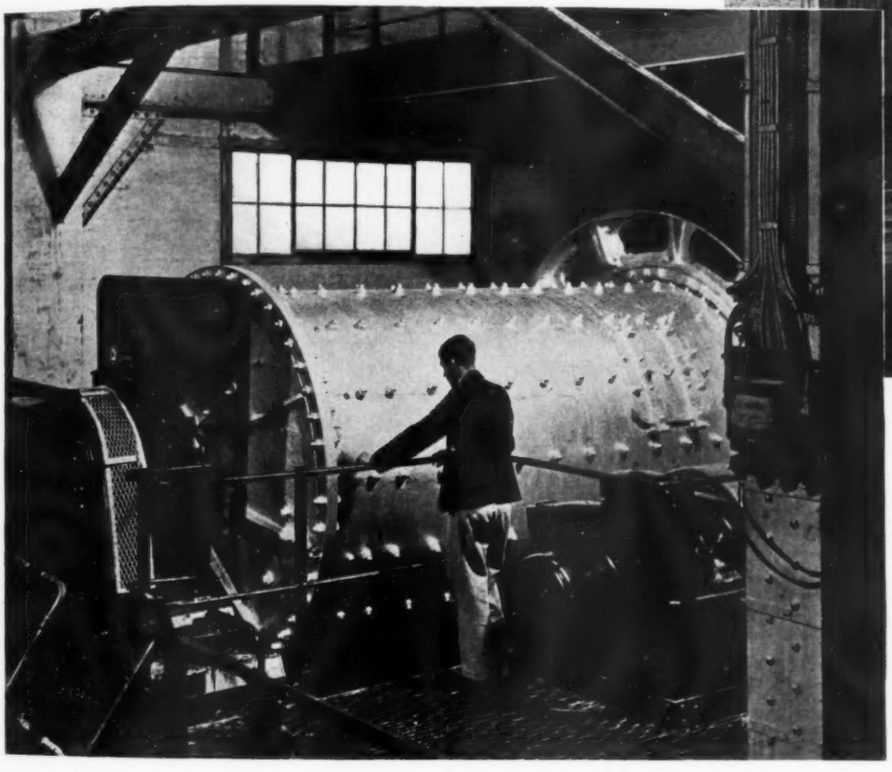
A broader knowledge of the ideal motor fuels and lubricants, together with more definite information of the structures of hydrocarbons which will fulfill these requirements will further stimulate the refiner in developing processes with which these products can be tailor-made chemically and physically. Increased costs of crude demands further consideration of improved methods of increasing the yields of products now in commercial use. Present knowledge of the possibilities of using gases and other relatively low value products for the production of substances which have relatively higher values, has led to consideration of the possibilities of the commercial use of such chemical processes.

Notwithstanding that methods are available for producing superior lubricating oils from various crudes, it is still important to utilize crude distillation methods which give maximum yields of distillates which are the initial products in the subsequent steps involved in the manufacture of lubricants. In the case of gasoline and kerosene, which have relatively low boiling points, it is not so difficult to establish when the maximum

yield of a given quality product is being approached, but in the case of the heavy lubricating cuts analytical methods have not been devised to establish the maximum yield of a given product available in the crude. These considerations should lead to further improvements of methods of crude distillations which will give higher yields of these valuable heavy fractions.

It has been shown that by careful separation of specific fractions boiling in the normal gasoline range, certain constituents of rather high purity can be isolated which are not only very superior motor fuels but which offer definite possibility of utilization in the manufacture of products now regarded in the fine chemical class. The major problem here is isolation of these fractions, which must be accomplished in crude distillation as well as subsequent steps, such as solvent extraction, and other methods of manufacture of the desired final products. Such methods of separation will make possible reconstruction of these hydrocarbons by dehydrogenation or isomerization for the production of superior motor fuel in the event that the refiner finds no outlet for "higher uses".





Demands of modern industry and transport are ever necessitating increased vigilance on the part of refinery technologists and wider knowledge and experience has led to consideration of the commercial use of chemical processes. Possible future refining technology is being explored in the hydrogenation plant at Billingham, England, pictured at right and below.

CRACKING

During 1936 the amount of cracked gasoline produced exceeded that of straight run for the first time in the history of the refining industry. Despite the fact that 260,000,000 bbl. of gasoline will be produced during 1937, cracking operations themselves have not been standardized, which in itself indicates that our knowledge of the subject is not sufficiently complete to set forth the final ideas of the design and operation of ideal cracking equipment.

Refiners have been so occupied with changing existing operations to meet the continual varying character of improved motor fuels that adequate consideration has not been given to the selection of the type of equipment and method of processing which will make the gasoline of the required quality at the least expense. The present knowledge of yields, rates and qualities of products obtainable by cracking, is not sufficient to permit the selection of what may actually be the most economical method. For example, no satisfactory method of predicting the maximum yields obtainable from a given cracking stock has been developed. Available correlations admittedly constitute rough approximations, as no allowance has been made for the effects of charge stock quality other than that of gravity. Such prediction of yields when applied to particular plant equipment must be adjusted to provide for the effect of such factors as crack per pass and product quality. It appears that the cracking art would be considerably enhanced with a broader knowledge of the general field of yield prediction.

Currently two general classes of cracking equipment are being installed; those which utilize coil-only cracking and those which make use of coil-and-soaking-drum. No comprehensive comparisons have been published of the relative merits of these two classes, though it would seem that a comprehensive comparison of coil-only and coil-and-drum cracking would be of interest to all refiners now contemplating the construction of new cracking equipment. In many of the larger installations the fractions of varying volatility are being segregated for separate heating and crack-

Development of the chemical ... of petroleum ... fining has ... possible the ... ufacture of ... er octane ... for automo... and aviation ...

Photo by Robert Yarnall Richie—Courtesy Gulf Oil Corp.

ing, under conditions most favorable for the particular fractions involved. No discussions have appeared in the literature to show the advantages from the standpoint of rates, yields and qualities of products realized by such zonic cracking as compared to the more usual cracking in mixed streams.

The recent past has been marked by gradual commercial application of developments in cracking made over a number of years. Notwithstanding the fact that there have been no disclosures of any major improvements in cracking methods, it cannot be concluded that new developments will not be revealed within the near future. The upward trend of crude prices has contributed to the desire for higher yields, and steps are being taken to utilize certain known methods of obtaining larger yields of more valuable products. The literature on cracking suggests the future use of means of promoting cracking reactions by recycling of gases within the cracking system, and by the injection of residual oil fractions at some intermediate point in vapor phase heaters. The cracking of residual oils to gasoline and coke, rather than to gasoline and fuel oil, should provide one simple means of increasing the ultimate yield of gasoline. In thermal-polymerization operations the temperatures are not very different from those now in use in commercial cracking operations, which would suggest the possibility of combining cracking and thermal-polymerization with substantially lower investment cost and improved fuel economy.

While substantial advance is being made in the utilization of gases produced in cracking, there is little or no published data on what is being accomplished in the suppression of gas and coke formation in cracking. By comparison of the carbon to hydrogen ratios of cracking stocks, it has long been evident that higher gasoline yields are theoretically possible. For a material suppression of gas and coke formation in cracking, it appears that recourse must be made to the use of catalysts. It is still apparent that considerable study is being given to this possibility from the number of patents of this nature being issued.

In an effort to increase the ultimate yield of gasoline from cracking, the trend has been toward the elimination of straight run fuel oils and towards the production of heavier cracked fuel oils while maintaining required viscosity. The U. S. Navy now permits an 8 degree minimum A. P. I. gravity for Navy fuel oil, and industry has long accepted even lower gravities for industrial use. Such low gravity fuels are desirable from the standpoint of improving the yield of cracked gasoline and in themselves are of superior quality, having relatively low viscosity and high heating values per barrel.

At present the furnace oil demand amounts to 110,000,000 bbl. per year, and continues to increase each year appreciably more than does the demand for other products. In order to supply the indicated future demands for furnace oils, serious inroads will be made on the materials previously available for manufacture of gasoline. It has been stated that furnace oils of the future will be exclusively cracked products, and there is reason to believe that these will be satisfactory substitutes for the virgin gas oils used in the past, but there are little published data to substantiate this or to indicate just what treatment is required to cracked cycle gas oils to make them satisfactory for use as furnace oils. The substitution of cracked gas oil, which is poor cracking stock, for virgin gas oil, which is a superior cracking stock, would permit the realization of higher gasoline yields from a given barrel of crude while meeting rapidly increasing furnace oil requirements.

With catalytic polymerization it is possible to utilize only unsaturated gases of relatively high olefin content. With this method one can utilize as motor fuel practically all butanes normally present in cracking plant gases. An outstanding

Operation of commercial units has shown that C_3 and C_4 hydrocarbons can be transformed into high quality motor fuel.

development of this operation is that by modification of the nature of the charge stock and operating conditions, it is possible to produce polymers which on hydrogenation yield a product which has 100 octane and, with the addition of small amounts of tetraethyl lead, even higher octanes are obtained.

Data have been published which show such large gains in performance in using this high octane gasoline in airplanes that their utilization in the immediate future seems imperative. While this superior gasoline can be produced at reasonable cost it is apparent that eventually these methods now available will have to compete with other promising methods. The scientific press has reported processes whereby, with the use of suitable catalysts certain olefin and paraffin hydrocarbons are combined with unsaturates to produce branch chain hydrocarbons, the nature of which can be controlled to give those qualities desired in superior aviation gasoline. While it is too early to predict the results of the use of such processes, its utilization may come as rapidly as the production of high octane gasoline by polymerization and hydrogenation, which has been a development of the past two years.

The above processes presuppose the availability of sufficient gases of the desired quality as starting products, and another possible attack in the production of the high octane gasoline is the conversion or isomerization of normal hydrocarbons to branch chain products. There has been substantial progress in this direction, though the research has been limited to the low molecular weight hydrocarbons.

It has been demonstrated by the operation of large commercial units that C_3 and C_4 hydrocarbons can be transformed to high quality motor fuel, using equipment very similar to that employed in conventional cracking operations. The advantage of such thermal polymerization processes is that their use is not limited to gases of relatively high olefin content, but offer a means of complete utilization of low molecular weight saturated compounds which otherwise would go into refinery fuel. While these thermal processes have been applied to refinery gases, it is apparent that their outstanding value will be their application in the conversion of excess C_3 and C_4 hydrocarbons available in the natural gasoline industry. It is indicated, however, that for economical operation relatively large plants are necessary and the recovery and collection of the feed stock at central locations in the necessary quantities, is a problem requiring a technical and economic solution.

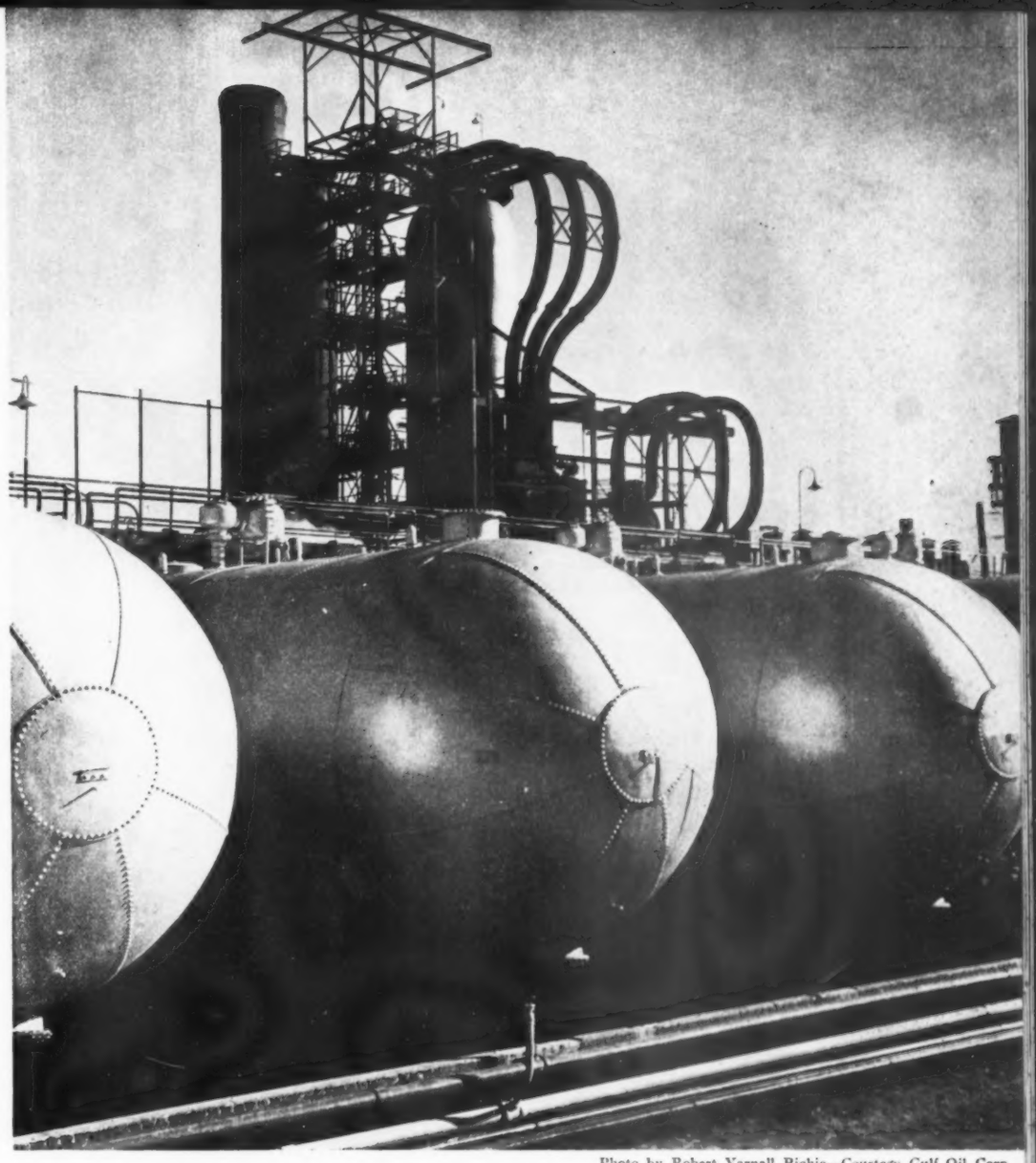


Photo by Robert Yarnall Richie—Courtesy Gulf Oil Corp.

There are two types of thermal-polymerization processes in use: one is accomplished by recycling of the condensibles along with the fresh feed under conditions of relatively high pressure and temperature, and the other method subjects the feed stock to relatively high temperatures and low pressures which are optimum conditions for the formation of unsaturates, which are then subjected to higher pressures and lower temperatures for polymerization. By this means it is claimed the polymerization may be controlled to form products of widely different characteristics. A final product containing pure aromatics may be formed, for instance; or by varying operating conditions a mixture of hydrocarbons closely resembling ordinary cracked gasoline may be produced.

These processes are quite new to the industry, and it is natural to expect that they have not reached their full state of development. It may be reasonably presumed that the cost of gasoline produced by polymerization will be greatly reduced in the future.

HYDROGENATION

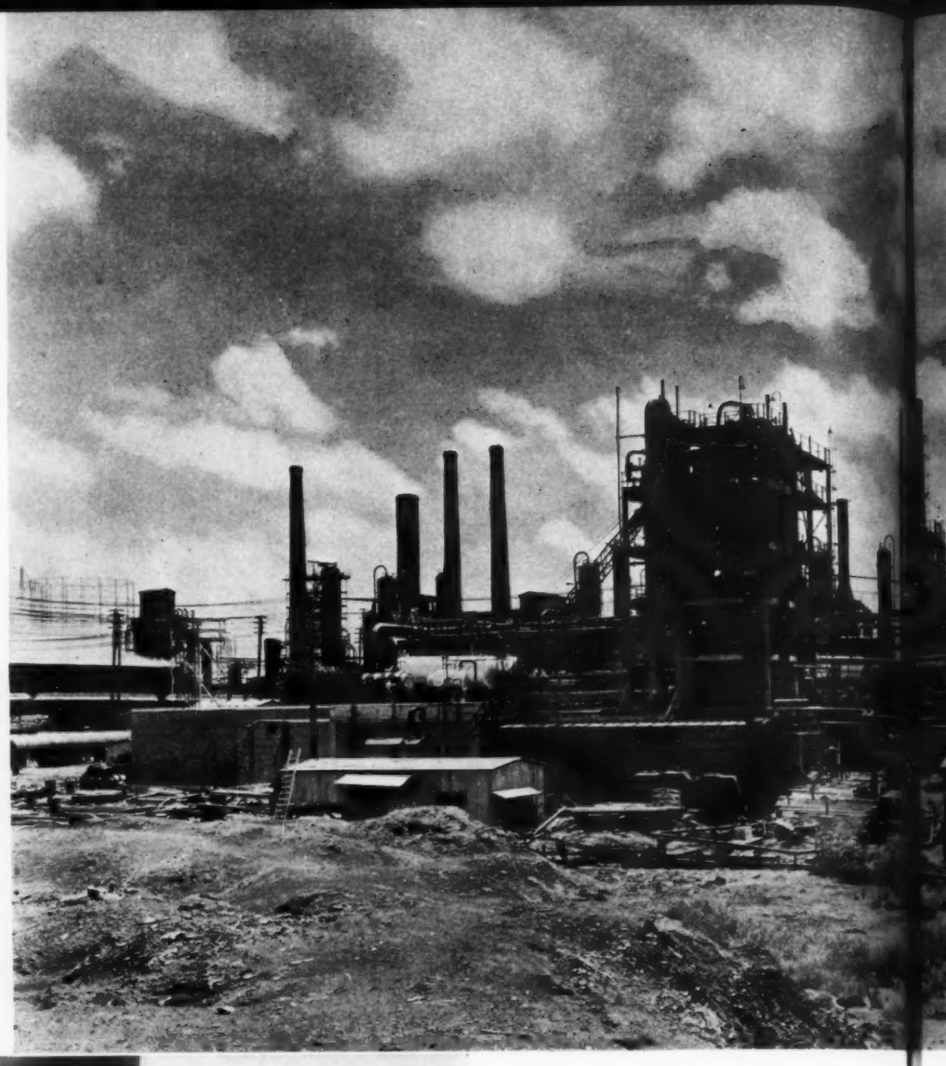
Continued large scale operation of hydrogenation plants in this country and increasing use of plants of this type abroad, assures us that such processes will be available for general use if the anticipated supply of petroleum is found to be inadequate in the remote future. Hydrogenation for the production of special products such as high octane aviation gasoline should come into general use in this country.

The dehydrogenation of paraffins is of importance as a substitute for reforming of gasoline and the pyrolysis of gases, and for the production of relatively pure hydrocarbons to be utilized as raw material for the production of polymer gasoline and the many organic materials which may be synthesized from olefins and aromatics. An important aspect of dehydrogenation is the ultimate utilization of the hydro-

gen liberated in the process. In the dehydrogenation of paraffins much relatively pure hydrogen will be cheaply supplied, which should accelerate the trend towards the use of hydrogenation in synthesizing high octane gasolines and special hydrocarbon by-products.

GASOLINE TREATING

The development of synthetic methods for the production of a wide variety of chemical products using the light petroleum fractions as source materials, may make this outlet competitive with the utilization of these light materials for conversion into gasoline. It is now realized that such materials as ethers, glycols, alcohols, acids, aldehydes, dyes, resins, color inhibitors, antioxidants, rubber substitutes, and sulphuric acid may be synthesized from light petroleum fractions. Their production on a large scale would make serious inroads on those light products now being utilized in the production of high octane gasoline and new sources and new methods for making superior motor fuels would of necessity have to be developed.



Right, Atlantic Refining Company's Point Breeze thermal polymerization plant; below, stillman on top of steam still tower, Whiting, Indiana.

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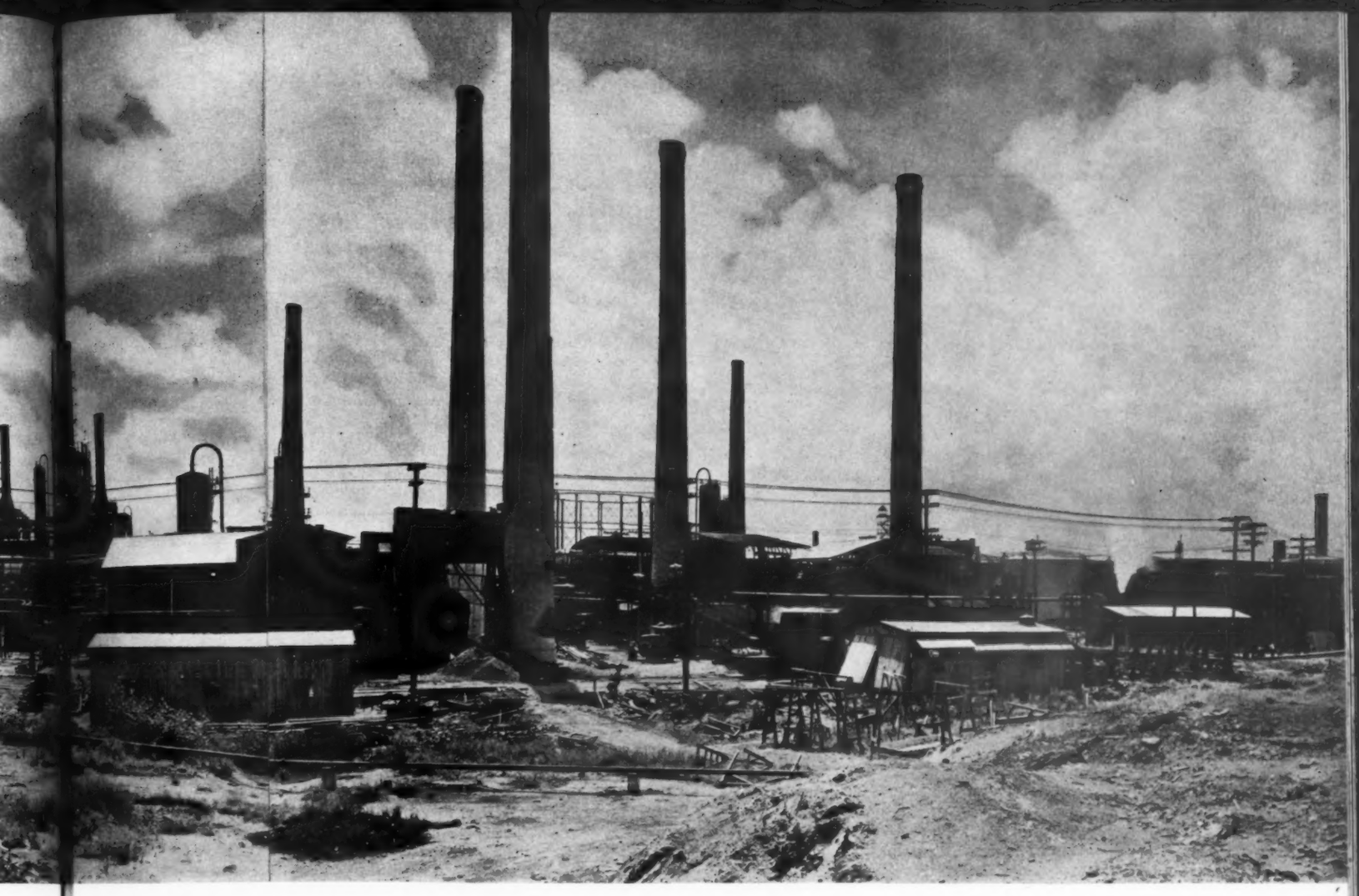
The use of inhibitors has greatly accelerated recently and the economies have been found to be such that the use of inhibitors will no doubt extend to the treatment of practically all cracked gasoline in the near future. A number of investigators have disclosed limitations of the doctor sweetening process, in that its use results in the formation of certain sulphur compounds which seriously increase the tetraethyl lead requirements in manufacture of high octane gasoline. To circumvent this difficulty a modified doctor sweetening process has been developed and introduced. Numerous installations employing copper salts as the sweetening agent have shown this method to be far superior to the doctor sweetening methods formerly used.

While lead requirements can be minimized by improved sweetening methods, it is indicated that lead requirements may be further reduced by removal of the mercaptans which enter in the sweetening reactions. It has been demonstrated that these mercaptans can be removed by simple caustic wash under proper conditions of contact time, temperature and caustic concentration. The economy of this operation is improved by the fact that the caustic used can be revivified at relatively little expense. It has not been proven that a



caustic wash alone is not satisfactory for finishing gasoline, since this will apparently accomplish the removal of hydrogen sulphide and low molecular weight mercaptans which at present may oxidize with the formation of free sulphur, resulting in a corrosive gasoline.

Although there has been no marked development in the treatment of kerosenes, there has been much activity in the production of furnace oils and Diesel motor fuels. One school of thought is that if Diesel engines are to gain in popularity manufacturers must design the engines to operate satisfactorily on fuels of average quality which are readily available at reasonable prices. On the other hand, certain Diesel engine designers and operators seek a superior fuel to improve their engine performance. From a refiner's viewpoint the problem is one of standardization and utilization, for whatever type of product is desired can be made. The relative costs of the products which can be selected for this use should be given adequate consideration by the designer and ultimate consumer.

Notwithstanding the very wide use of furnace oil there is very little published information on the essential characteristics of a satisfactory product. In some cases straight run and cracked furnace oils are acid treated and rerun at appreciable expense to decrease apparent tendencies toward sludging during storage and handling, but there is no published evidence that such treatment is required. While at present there is no gravity specification for domestic furnace oil, there is no proof that the more aromatic products available as cracked gas oils are satisfactory household burner fuels. It would appear that the use of additives to furnace oils as a means of improving its stability would bear investigation as a possible source of substantial economy in preparing satisfactory fuel for domestic burners.

LUBRICATING OILS

During the last two years the solvent refining of lubricating oils has come into general use. The reported capacity of the units now operating or under construction, 60,000 bbl. per operating day, should go far toward meeting the lubricating oil demand which in 1936 was 22,600,000 bbl. or 62,000 bbl. per day. Of the 52 commercial installations, a dozen or so different combinations of solvent are used, the most significant being furfural, duosol, chlorex, sulphur dioxide, phenol and nitrobenzene for solvent extraction and acetone-benzol, propane, barisol and methyl-ethylketone-benzol for solvent dewaxing.

The fields of application of the various solvents in use have been outlined in numerous published articles. The solvent refining problem is one which each individual refiner must solve by determining how well the various solvents can handle the crude lube stocks available and make the type of products desired. In general the extraction solvents fall into two classifications, the single refining solvents and the multiple refining solvents. The former are generally found useful only in treating lubricating distillates—while the multiple solvents may be used in the treating of both distillates and residual lubricating stocks.

The design, construction and operation of these new processes has introduced many technical problems which, because of lack of fundamental data and sufficient operating experience, still remain unanswered. Numerous laboratory control methods have been used which give very good correlation with plant operations. These refining processes would be placed upon a more scientific basis, however, by the development of a simple laboratory method of determining the best operating conditions to be employed in processing a large variety of stocks to make the wide

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range of products normally encountered in the average refinery. Some simple means of determining the optimum solvent dosage and the conditions of time and temperature which will assure the production of the maximum yield of finished oil from a variety of lubricating stocks, would assist materially in the operation and control of the commercial solvent refining processes now in use.

The large demand for solvent treated oils has forced the refiner to operate all such equipment to the highest capacities attainable while producing quality products. As more solvent treating equipment is installed and the capacity of existing equipment more closely approaches the demand for solvent refined oils, more consideration undoubtedly will be given to the relative economics of all processes and the relative economy of various schemes which may be used to operate each process.

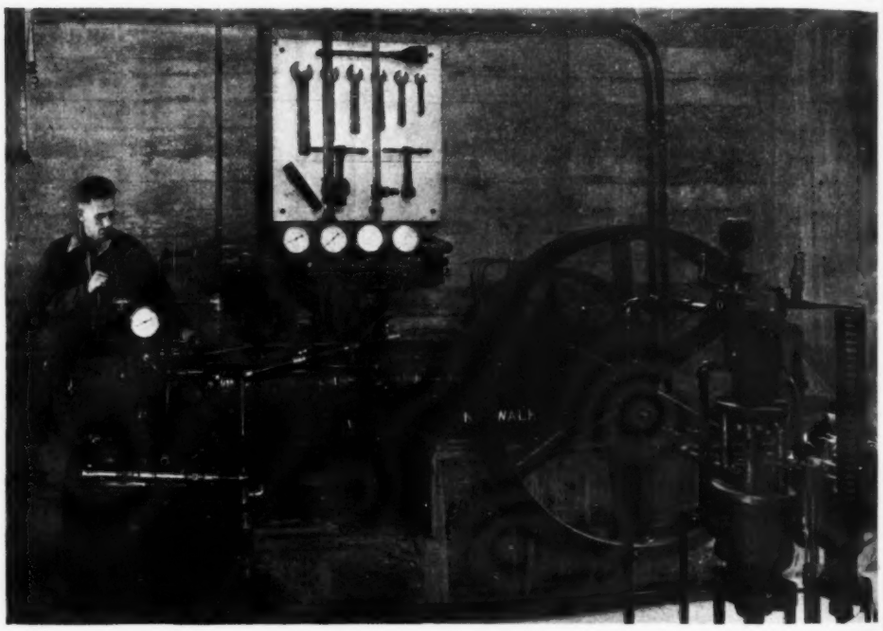
As knowledge of the fundamental nature of solvent fractionation is more completely understood, changes and improvements will be made in the processes now in use. New applications of step counter flow operations or the development of more efficient packed towers may prove economically desirable. To obtain improved control of the solvent process substantial changes in operating methods may prove desirable.

It is expected that the fundamental studies of the mechanics of lubrication and the study of surface films will modify our present theories of lubrication and result in the more intelligent determination of the types of lubricants desired. It is recognized, however, that at present there is but one satisfactory quality test for motor and industrial lubricants — actual trial under operating conditions. In the last several years the use of addition agents to motor oils either to enhance some characteristic already present or to impart a useful characteristic which is lacking, has increased considerably. Oiliness agents, viscosity and viscosity index improvers, pour inhibitors and oxidation and corrosion inhibitors have been used in the production of large quantities of high quality lubricating oils by the leading manufacturers. Addition agents have been found especially useful in the lubricants for the high pressure gears, which recently have been found so desirable in industry and in motor cars, in the latter being popularly known as the hypoid gears.

It seems safe to predict that further advances in engine design which place more rigid requirements on lubricants will be met by the increased use of addition agents. Attention has been called to the need of evaluating oils containing additives by actual performance tests rather than by comparison with the properties of the older lubricating oils. For example, there are at present a number of oxidation and corrosion inhibitors which can be shown to have highly desirable characteristics for maintaining cleanliness and for eliminating completely bearing corrosion, but which at the same time result in indicated poorer qualities by certain standard oxidation test ratings of oils to which they are added.

In considering means of obtaining the desired qualities of lubricants, the possibilities presented by synthesis must be considered. The synthetic oil may consist, for example of a single compound or a mixture of a few pure compounds; or perhaps a wider mixture of hydrocarbons of unknown structure, but all conforming to a preferred type. Many single hydrocarbons have a very high viscosity index and are free from carbon residue, but in general these have high melting points. By mixing several of these pure compounds, the melting point becomes much lower than that of any constituent. Excellent motor lubricants have been made by polymerizing naphthas obtained by cracking wax and reference is made in the literature to preparation of lubricating oils with interesting characteristics by the chlorination of certain wax fractions followed by condensation. Such synthetic methods of lube oil manufacture have been generally known for many years and the fact that little or no commercial development of these processes is in progress at the present time indicates that other methods of producing high quality lubricants have been found more desirable.

Careful testing (left) and hydrogenation research (below) is being carried out in the United States by both government and private enterprise.



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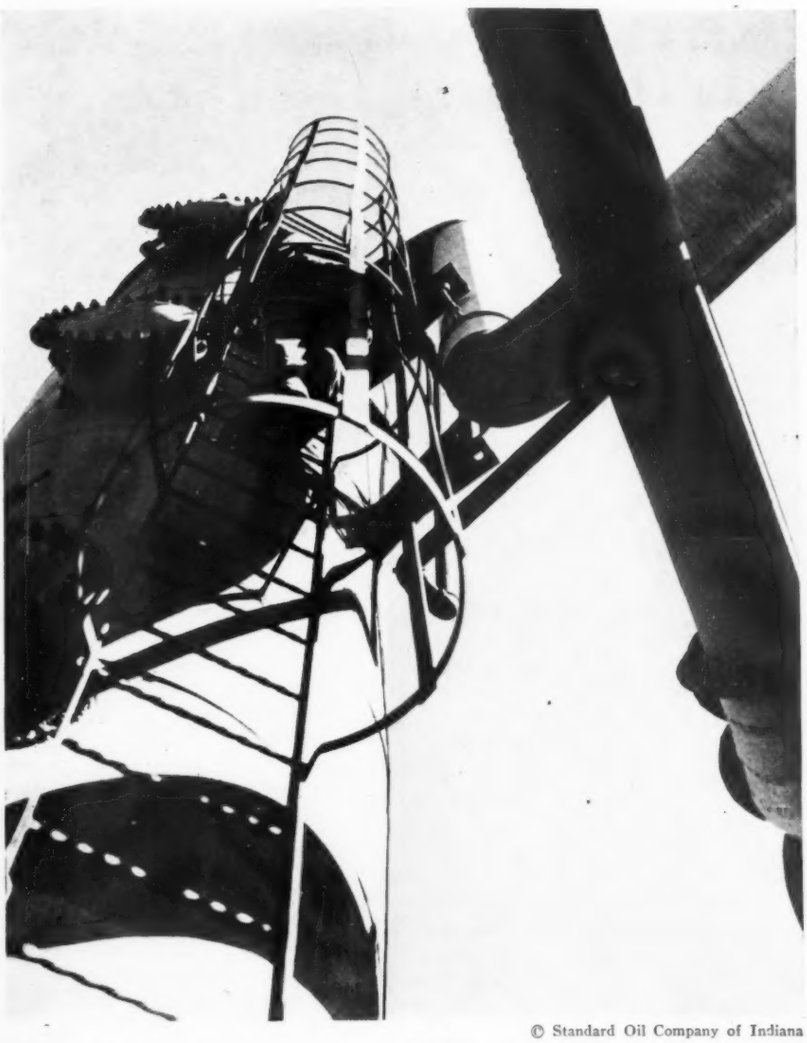
Certainly there is no agreement as to whether future lubricants should be made by synthetic processes such as have been mentioned, or whether they may better be made by intensive refining of a selected petroleum fraction to furnish a cheap high boiling base to which the desired qualities may be given by the addition of small quantities of synthetic materials. The general trend now appears to favor the latter method — the use of motor oil addition agents.

It is possible that the use of solvent refining would be promoted by the potential chemical uses of extracts and waxes from solvent refining and solvent dewaxing. The asphaltenes, aromatics, naphthenes, naph-



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Climbing steam still tower at Indiana Standard's Whiting refinery.

thenic acids, resins and waxes removed in these operations contain compounds that may be utilized in the preparation of countless organic materials for which considerable demand already exists in industry and for which undoubtedly new uses could be found. It is quite evident that the development of such methods of by-product disposal, along with catalytic polymerization, hydrogenation, alkylation, isomerization and other methods of synthesizing organic compounds will find a prominent place in the future development of the petroleum industry.

While solvent refining has resulted in the complete elimination of acid treating in finishing some lubricating oils it is not anticipated that the use of acid will be entirely eliminated in the treatment of all lube stocks. In some cases excessive filtration costs where solvent refining alone is employed makes the use of small amounts of acid desirable from an economic standpoint as well as from the standpoint of quality of the finished products. The extent to which acid treating is used in conjunction with solvent refining by particular refiners depends often upon the overall balance of capacities of available lube oil treating and filtering equipment. Acid treating methods, themselves, by the use of centrifuges for the separation of oil and sludge, have improved considerably over the old batch acid treating systems.

Methods of efficient recovery of oil from contact filter clay are being more actively investigated. Certain methods now available involving solvent extraction and the use of mechanical presses, seem quite costly and are not in general use. A continued trend toward higher crude prices would encourage further research and may result in the universal adoption of such schemes for recovering the oil now lost in contact filter clays. It is conceivable that some process involving oil recovery and regeneration of clays will be developed and will effect a reduction in clay treating costs.

ASPHALT

Despite a 28 percent increase in demand for asphalt products in 1936 over 1935 and further large increases in the current demand for these materials no substantial change has been made in their manufacturing methods. There has been much modernization of equipment and the producing capacity has been increased by the installation of high capacity vacuum tube stills. Substantial improvements have been made in the design and operation of much of the older asphalt equipment.

In most cases the increased demand for products has been met by processing a greater amount of domestic crudes to asphalt. Increased costs of foreign crudes has discouraged their use and the adoption of lower specific gravities in finished asphalt specifications has permitted the more general substitution of domestic crudes. The refiner has experienced no serious difficulties in meeting the increased demand of products by processing domestic crudes. As the trend toward the use of domestic crudes increases certain refiners, particularly those producing roofing materials, may have difficulty in meeting specifications based on long use of Mexican and Venezuelan crudes.

One outstanding product development is the use of emulsified asphalt for soil stabilization. This product has been used largely on the construction of runways for airports, and its applicability leads to its general use in the stabilization of sub grades for secondary roads, which opens a field in which large quantities of bituminous materials may be sold in the future. These emulsified products require rigid specifications but the refiner has encountered no unusual difficulties in meeting them.

No reliable information is available to show the proportion of cracked residues used in the preparation of asphalt but it is believed the amount is not large. Recent general adoption of solvent solubility tests for paving asphalts seems to preclude the use of cracked residues in this use. There are some who contend that cracked residues make suitable asphalts for a wide variety of purposes when properly applied, and apparently the use of these stocks in the manufacture of asphalt will continue.

The applicability of extracted residues from the solvent refining of lubricating oil, in the preparation of asphalts has been generally recognized, but their use has been discouraged because of their relatively high susceptibility, the large spread between penetrations at different temperatures marking this material as an inferior asphalt product. Investigation of the use of these materials as asphalts has merely begun, however, and there is much possibility that suitable asphalts will eventually be made from these substances either directly or by blending with materials from other sources.

TEN YEAR TREND Toward Larger Refining Units, Traced by Bureau of Mines

By Raymond Dickey

A CONSISTENT trend toward larger refinery units, particularly in the Texas Gulf Coast area, is shown by the Bureau of Mines of the Department of the Interior in a recent compilation of data.

Positive proof of the growth into larger units is found in a quick comparison of the national refinery picture as of the close of 1936 and the end of 1926, the decade resulting in an increase of only 25 percent in the number of refinery units, although daily capacity virtually doubled.

Specifically, 115 refineries with a daily capacity of 451,950 bbl. were located in the Oklahoma-Kansas district; 84 refineries, with a daily capacity of 715,900 bbl. in California; and the Inland Texas district had 82 refineries with a capacity of 210,430 bbl.

Discovery of the East Texas field, the desire of companies to cut down maintenance cost, and the desire of shippers to avail themselves of tankship freight rates led to the drift toward larger type refineries in the Texas Gulf Coast district, sharp on the heels of the rapid construction of refineries started by the East Texas field.

To show this tendency, the January 1, 1937, figures show a total of 31 refineries on the Gulf Coast, having a capacity of 780,000 bbl. per day. Probably the most significant thing in regard to these figures is that only two refineries are shut down in the Texas Gulf Coast district, the pair having a capacity of only 12,000 bbl. a day. Contrast today's capacity with 1926, when the Texas Gulf Coast refineries had only a 344,300 bbl. daily capacity.

The trend toward larger refineries can be seen more clearly when one finds that, during the 1926 period, there were 26 refineries in the Texas Gulf Coast district. A sharper picture is presented by noting that the number of refineries has increased approximately 20 percent in that district since 1926, but total production from the Texas Gulf Coast district has increased by about 260 percent. This gives a true indication of the trend toward larger units.

Another factor of wide interest is the increase in cracking units in the refineries. In 1926, 464 refineries had but 131 cracking units, or approximately one in every four plants. In 1937, 423 refineries had 228 cracking plants, or almost one in two.

The drop in both number of refineries and total capacity in the Appalachian district is considered significant by some authorities. On January 1, 1936, there were 52 refineries in this district with a total of 177,525 bbl. daily capacity. On January 1, 1937, the number of refineries had dropped to 45, with a total daily capacity of 161,000 bbl. Also interesting is the increased capacity of the Indiana-Illinois district despite a drop from 57 refineries on January 1, 1936, to 56 on January 1, 1937. Capacity, however, rose from 475,130 bbl. daily to 519,000 bbl. on January 1, 1937.

Also of interest is the fact that there has been a tremendous decrease in the number of plants in the Inland Texas district. On January 1, 1936, this district had 187 refineries with a total daily capacity of 503,999 bbl. On January 1, 1937, the capacity had dropped to 462,000 bbl. daily from 146 refineries.

The capacity of all completed plants in the country on January 1, 1937, was 4,294,881 bbl. of crude oil daily. This, however, does not indicate that that much crude could have been run, because inoperative plants, having a daily capacity of 328,265 bbls., would have to have been modernized at prohibitive costs. Furthermore, much of the shell-still capacity of the operating plants, estimated at about 1,500,000 bbl., probably is in poor condition, reports the Bureau of Mines.

Material gains in capacity were registered chiefly on the East Coast, in Indiana-Illinois, and on the Texas Gulf Coast. California, the leading district, remained practically unchanged, registering a small increase from 847,000 bbl. on January 1, 1936, to 870,000 bbl. January 1, 1937. Along the Texas Gulf Coast, with only 31 plants, production virtually matches California's capacity and is far ahead of that state in crude runs.

Doubtless, according to the Bureau of Mines, crude runs should be raised even above the high levels now prevailing since considerable pipe-still and cracking capacity now operating on unfinished oils could be converted to crude. Considerable cracking capacity has been converted to run on crude oil much after the manner of the new combination units. The crude oil capacity of converted cracking units on January 1, 1937, was 217,885 bbl.; and that of combination units was 432,300 bbl.

In cracking capacity, the East Coast continued to lead. But, says the Bureau of Mines, the Texas Gulf Coast district will have a greater capacity than the East Coast as soon as its current building program is completed and will then go to the head of the list.

To sum up, the situation seems to be about as follows:

Definite trend toward more cracking units. Increase in the size of refineries. Dismantling of outmoded equipment and refineries. Move toward locations where more favorable freight rates prevail, particularly toward Texas Gulf Coast which is experiencing a great refinery building program and also profiting from being near production area. Trend toward Indiana-Illinois district capacity increases due to centralized locations and increased production in that area. Trend toward increase in cracking capacities of plants operating and under construction, but decline in idle cracking capacity.

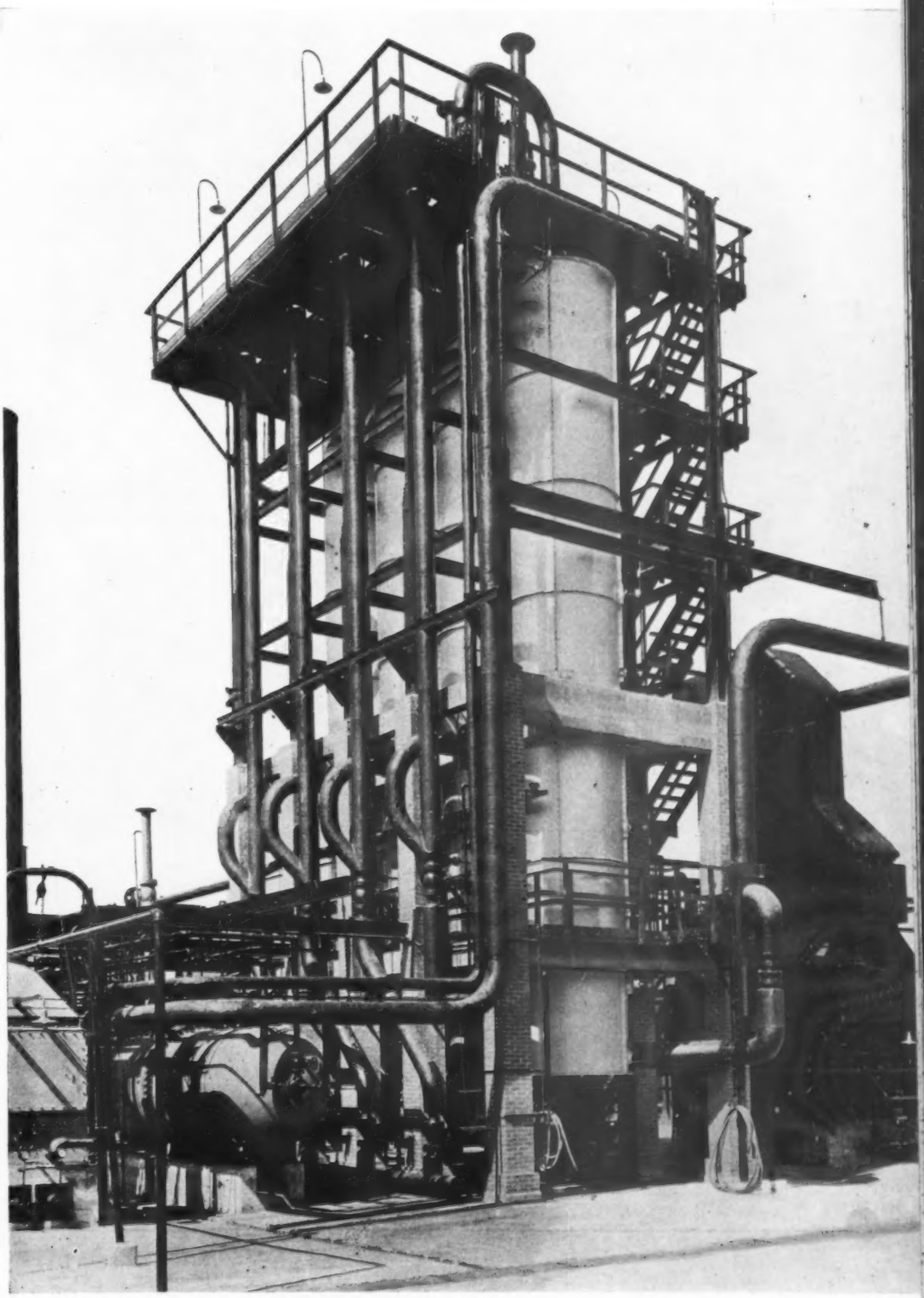
The capacity of operating units, including the cracking capacity of combination units, increased from 1,994,868 bbl. on January 1, 1936, to 2,077,325 bbl. on January 1, 1937, or approximately four percent. Since the charge to cracking stills increased 19 percent in that same period, it is seen that an increase in the operating ratio outweighed the comparatively small gain in capacity.

LOCATION AND CAPACITY OF U. S. REFINERIES

District	Total No. of Refs. (Operating & Shut Down)	Total Capacity Bbl.
Jan. 1, 1926		
East Coast	19	442,800
Appalachian	30	138,750
Indiana, Illinois, etc.	41	214,850
Oklahoma, Kansas, etc.	115	451,950
Texas Inland	82	210,430
Louisiana & Arkansas Inland	28	75,670
Rocky Mountain	42	157,571
California	84	715,900
Texas Gulf Coast	18	344,300
Louisiana Gulf Coast	7	130,500
TOTAL	464	2,858,471
Jan. 1, 1936		
East Coast	26	617,600
Appalachian	52	177,525
Indiana, Illinois, etc.	57	475,130
Oklahoma, Kansas, etc.	79	491,109
Texas Inland	187	503,999
Louisiana & Arkansas Inland	27	119,150
Rocky Mountain	113	99,174
California	76	847,110
Texas Gulf Coast	25	650,300
Louisiana Gulf Coast	5	136,000
TOTAL	647	4,117,047
Jan. 1, 1937		
East Coast	25	671,000
Appalachian	45	161,000
Indiana, Illinois, etc.	56	519,000
Oklahoma, Kans., etc.	65	463,000
Texas Inland	146	462,000
Louisiana & Arkansas Inland	22	127,000
Rocky Mountain	100	107,000
California	77	870,000
Texas Gulf Coast	31	780,000
Louisiana Gulf Coast	5	136,000
TOTAL	572	4,395,000

CATALYSIS Offers Accurate Control of Hydrocarbon Decomposition

By V. N. Ipatieff



An 8,000,000 cu. ft. per day capacity Universal Oil Products Company catalytic gas polymerization plant.

THE HISTORY of the development of the petroleum industry can be traced back over a period of more than one hundred years. The first equipment for the distillation of petroleum was installed in Russia about 1830 for the purpose of separating kerosene to be used as illuminating material.

The technology of petroleum developed very slowly prior to the beginning of the twentieth century, and workers in this field devoted their attention wholly to improvements in the distillation process and purification of the products.

The development of the automobile and the aeroplane has brought new problems for the petroleum industry which necessitated a search for new methods in processing petroleum. On the one hand it was necessary to develop on a large scale the production of gasoline and on the other hand supply the modern gasoline engines with new types of lubricating oils.

The demand for large quantities of gasoline brought about the introduction of a new process of cracking, and at the present time about 50 percent of the gasoline is obtained through the use of the cracking process, the anti-knock properties of this gasoline being superior to the natural gasoline obtained by distillation of petroleum. The tremendous quantity of petroleum used in the cracking process furnishes as a by-product a considerable quantity of gases, amounting to about 10-15 percent of the petroleum charged. These gases contain, on the average, about 16 percent olefins and as these hydrocarbons possess great reactivity, it is desirable to utilize them for the production of compounds which have value for the different industries. For example, if all the gases obtained from the cracking process were subjected to polymerization for the conversion of olefins into gasoline, we would have the following picture:

The yearly production of cracked gas in the United States[1] as a by-product of the cracking process is 300,000,000,000 cu. ft. of which 50,000,000,000 cu. ft. are olefins. The latter have a potential production of 1,000,000,000 gal. of polymer gasoline of 81 octane number. The total gasoline production in the United States in 1936, straight run and cracked, was 20,000,000,000 gal. of about 65 octane number.

After the polymerization of olefins from

[1]Ipatieff, Corson and Egloff, Ind. Eng. Chem. 27, 1077 (1935).

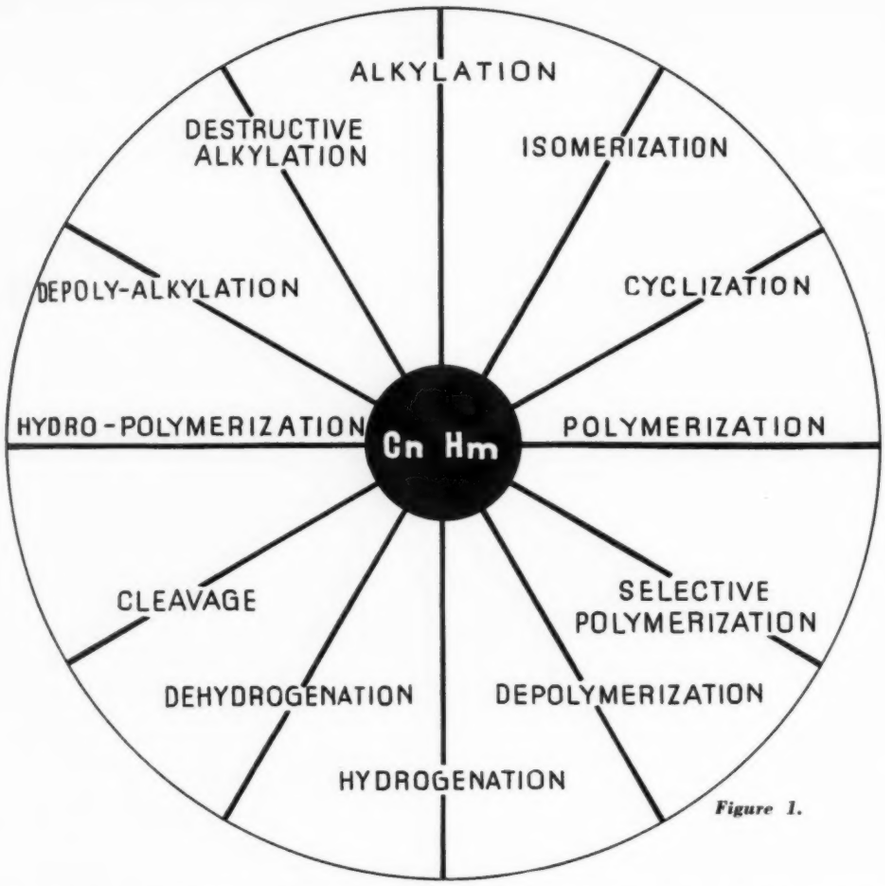


Figure 1.

the cracked gases the remaining paraffin hydrocarbons can be converted into olefins by means of dehydrogenation, and the latter can be again subjected to polymerization.

On the other hand, certain olefins contained in the cracked gases or obtained by dehydrogenation of natural gas, can be subjected to polymerization under special conditions and converted into very viscous lubricating oils. The latter, when mixed with natural oils, give a product having properties which meet the requirements of modern automotive engines.

Unsaturated hydrocarbons from cracked gases as well as those obtained from natural gas find application in the technology of organic substances for the production of such compounds as aldehydes, ketones, alcohols, glycols, acids, ethers, etc.

The above statements indicate the tremendous importance of petroleum hydrocarbons, especially of the gases, as starting material for the production of various organic compounds, which in turn, can be converted into more complicated compounds.

Due to the present requirements of the petroleum market and other branches of the industry we must turn our attention to the development of methods of treatment of petroleum distillates and cracked gases, which will permit us to utilize most economically the expensive starting material, that is petroleum. Also, the quality of the required products must be higher than that of the products obtained through the use of the accepted methods.

The history of the development of the petroleum industry during the last ten years indicates that it has now become necessary to introduce new catalytic methods, which have received such wide application in the field of synthesis of organic compounds during the last quarter of a century.

Up to the present time, in order to obtain high grade gasoline from petroleum, the latter was subjected to cracking at high temperatures, (500-510 deg. C), and to achieve the best results attention was paid mostly to the physical factors involved, such as temperature, pressure, time of contact, etc. Although this thermal process has made it possible to obtain tremendous quantities of gasoline, it still represents a very complicated chemical reaction. We are unable to control at will the different phases of the reaction so as to direct the whole process to the most desirable products. If, instead of using such a crude method as cracking, we could introduce more delicate catalytic methods of decomposition of hydrocarbons, we undoubtedly would obtain great advantages in the control of this reaction. The necessity and usefulness of introducing new catalytic methods in the petroleum industry, may be illustrated by an example from organic technology, which will immediately show the advantages which could be obtained by substituting a delicate catalytic method for a rough thermal one.

Thirty-five years ago no one could explain why the pyrolysis of alcohols at 400-600 deg. C. yielded various products such as hydrogen, carbon monoxide, aldehyde, methane, etc.

The thermal decomposition of alcohols, especially ethyl and isoamyl alcohols, had been studied by many outstanding chemists for almost 100 years, but not one of them could explain how the decomposition took place and why such diverse products were obtained.

However, after the author had discovered that certain catalysts influence the decomposition of organic compounds at high temperatures, it was possible not only to understand the exact manner in which the decomposition proceeds, but also to obtain selective action by various catalysts.

We were able to establish, from the very beginning of our investigations, that some metals and their oxides promote aldehyde decomposition of alcohols; that other oxides promote ethylene decomposition; and that still other oxides make it possible to obtain diolefins from the alcohols.

A catalyst causes the decomposition of an organic compound to take a certain direction, due to its specific chemical and physical properties. Taking into considera-

FIG. 2.

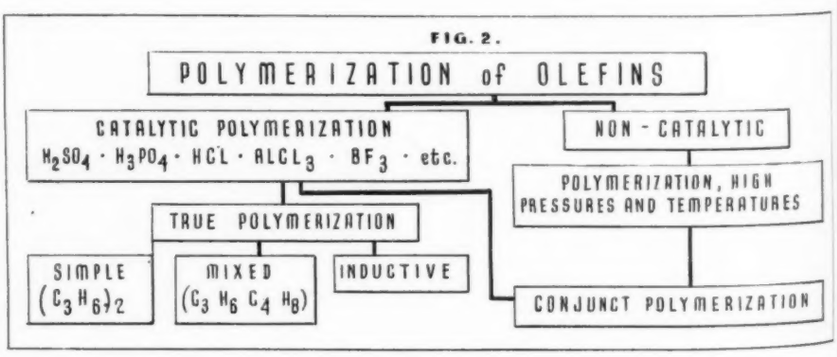
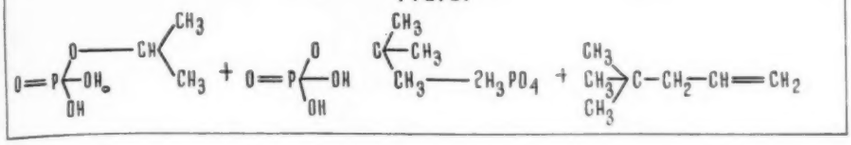


FIG. 3.



tion the most vital problems facing the petroleum industry, we believe that a new period of its development has begun, the catalytic period.

The necessity of introducing catalysis for obtaining various products from petroleum is evident both from the scientific and the economic points of view. We know that catalytic methods have great advantages, and they already occupy a firm place in chemical industry.

In the petroleum industry they will be perhaps even more important, since the reserves of this valuable raw material should be conserved by using them to better advantage. The more rational utilization of petroleum constitutes a problem of great importance for the chemist as well as for the engineer.

In order to show that the catalytic period has become a reality, several catalytic processes which are in commercial operation may be mentioned. Figure 1 lists the most important types of catalytic reactions of the various hydrocarbons found in petroleum. These reactions at the present time are being investigated in various scientific and research laboratories.

We are in a position to say that all the reactions listed in Figure 1 will find broad application in the petroleum industry. Laboratory experiments fully justify this statement.

Some of these reactions, such as true polymerization[2] and also selective and mixed polymerization, are already applied on a large scale; and hundreds of thousands of barrels of excellent gasoline, with high octane number, are being produced in the United States by these reactions.

Let us consider, for example, the advantages of using the catalytic method in the polymerization reaction of olefins from cracked gases. Figure 2 shows the various types of polymerization with and without a catalyst.

Thirty years ago[3] the author showed for the first time that for the polymerization of ethylene and other olefins high pressure and temperature (about 350-400 deg.C.) are necessary. Under such conditions the polymerization of olefins proceeds very rapidly in the absence of catalysts and as a result we obtain a mixture of three types of hydrocarbons, namely, olefins, paraffins and naphthenes. An investigation of this reaction[4] indicated that the normal reaction—polymerization of olefins—is accompanied by other reactions such as cyclization of olefins, their conversion into naphthenes; the latter undergo dehydrogenation and the liberated hydrogen *in statu nascendi* hydrogenates the olefins converting them into paraffins. In this manner we observe simultaneous reactions of dehydrogenation and hydrogenation. The energy necessary for these reactions is liberated during the polymerization reaction.

In this manner, the polymerization of olefins under pressure is composed of several reactions proceeding simultaneously, the reaction rates depending upon the temperature. We suggested that this type of polymerization be called "conjunct polymerization".

FIG. 4.

I. $2C_nH_{2n} \longrightarrow C_{2n}H_{4n}$	OLEFIN
II. $C_{2n}H_{4n} \longrightarrow C_6H_{10}\ (R_2)$	NAPHTHENE
III. $C_6H_{10}(R_2) \longrightarrow C_6H_4(R_2) + 3H_2$	AROMATIC HYDROCARBON
IV. $C_nH_{2n} - H_2 \quad C_nH_{2n+2}$	PARAFFIN

Up to the present time it has not been possible to obtain the "true" polymerization of olefins under pressure, in which case the product should consist only of olefins.

This method of polymerization of olefins from cracked gases as well as from pyrolyzed natural gases is utilized at the present time on a large scale in the United States (Phillips Co. and others). For the carrying out of this process apparatus which can stand high temperatures and pressures is required.

In certain cases, however, this method has a basis for its application, especially for gases which have a low olefin content and consist mostly of paraffin hydrocarbons. These gases must first be converted into olefins by means of pyrolysis. The two processes of pyrolysis and polymerization can proceed simultaneously in the same apparatus but high pressures and temperatures are necessary.

When the olefin content of the cracked gases is considerable, the application of the above method of polymerization, that is, in the absence of catalyst and using only high pressures and temperatures, becomes irrational. Here it is necessary first to remove the olefins from the gases by subjecting them to catalytic polymerization, then catalytically to dehydrogenate the remaining paraffins, and subject the formed olefin hydrocarbons to catalytic polymerization. Calculations[5] have shown that even if the remaining paraffins are subjected to pyrolysis only, it is more advantageous first to remove the olefins by catalytic polymerization, rather than subject them to the action of high temperature and pressure.

The best catalysts for the polymerization of olefins at the present time are orthophosphoric[6] and pyro-phosphoric acids. Metaphosphoric acid does not appear to be a catalyst for polymerization. From a practical point of view it is much more advantageous to use phosphoric acid in a solid form, for which purpose it is necessary to mix the acid with a carrier. The latter is preferably selected so that the resulting solid catalyst contains a relatively high percentage of phosphoric acid. The catalyst develops a high speed of reaction and retains its activity for a long period of time.

The catalyst discovered by the author[7] can, depending upon the conditions of the experiment, give different types of polymerization: true and conjunct polymerization.

For example, if we subject propylene to polymerization we obtain the following polymers:

$$C_3H_6 \longrightarrow C_6H_{12} \longrightarrow C_9H_{18} \longrightarrow C_{12}H_{24}$$

Under these conditions the last polymer is the tetramer of propylene.

The catalytic reaction proceeds in two phases, an ester of phosphoric acid is formed, and later, two molecules of the ester combine, liberating the acid and forming the dimer, etc.

The possibility of a partial depolymerization of the higher polymers insures the formation of other intermediate olefins.

[2]Ipatieff "Catalytic Reactions at High Pressures and Temperatures," Macmillan Co., New York, 1936.

[3]Ipatieff, Journal of the Russian Phys.—Chem. Soc. 1906.

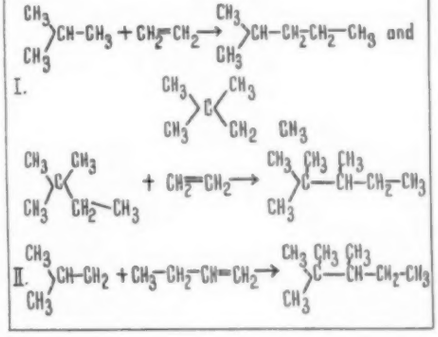
[4]Ipatieff and Pines, Ind. Eng. Chem., 27, 1364 (1935); Ipatieff and Corson, Ibid., 28, 800 (1936).

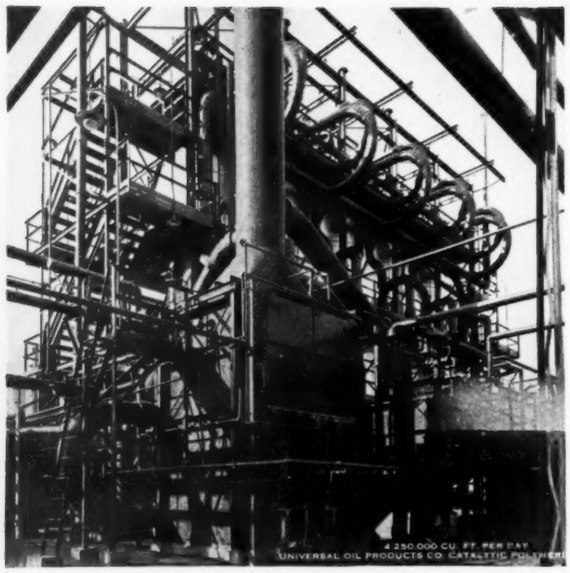
[5]Egloff and Thomas, Ind. Eng. Chem. 28, 324 (1936).

[6]Ipatieff, Ind. Eng. Chem. 27, 1067 (1935); Ipatieff & Corson, Ibid., 27, 1069 (1935).

[7]Ipatieff, U. S. Patents, 1,993,512; 2,018,065; 2,018,066; and 2,020,649 (1935).

FIG. 5.





Catalytic polymerization plant of Sinclair Refining Company.

If the polymerization of propylene is carried out in the presence of another olefin, as for example, one of the butylenes, we obtain *mixed polymerization* which proceeds according to the scheme shown in Figure 3.

In such manner, catalytic polymerization permits us to couple various olefins with each other and to obtain higher olefins, several of which, when subjected to hydrogenation, give paraffin hydrocarbons having such high octane number that they can be used in the highest type of aviation gasoline. This example illustrated the fact that the application of the catalytic method for polymerization of olefins makes it possible to achieve results, practically 100 percent yield and excellent octane number, which can not be obtained by the use of the thermal methods and high pressures.

If the polymerization of olefins is carried out in the presence of phosphoric acid catalysts under atmospheric pressure, but at higher temperatures, we obtain considerable quantities of other hydrocarbons; paraffinic, naphthenic and aromatic. This type of polymerization is called "conjunct polymerization" because in this case several reactions take place simultaneously: cyclization of olefins into naphthenes, dehydrogenation into aromatic hydrocarbons, and hydrogenation of the low boiling polymers by the hydrogen liberated *in statu nascendi*. The scheme of polymerization of olefins shown in Figure 4 illustrates the major reactions taking place in this type of polymerization which explains the formation of all types of hydrocarbons. These major reactions are, of course, accompanied by side reactions in the form of depolymerization, isomerization, etc.

Turning to another, at the present time very important reaction of dehydrogenation, we find that with the aid of the catalytic method much better results are obtained.

When pyrolysis of paraffins, rather than catalytic dehydrogenation, is employed for the production of olefins, experiments and calculations show that the yield of the olefins is considerably lower, and that the hydrogen is contaminated by such gases as methane, ethane, etc., which diminishes its value for hydrogenation.

Another very interesting reaction was discovered by the author[2], dealing with the direct inter-reaction of paraffins and olefins in the presence of different catalysts. This reaction is superior to the Friedel and Crafts reaction. The latter requires the preliminary preparation of alkyl halides, and it is possible to introduce radicals into hydrocarbon molecules only through their agency.

However, the alkylation of isobutane by ethylene and butylene produces directly a good yield of isooctane having a high octane number (See Figure 5).

By this method we can produce various saturated hydrocarbons of isostructure, such as isoheptane, isodecane, etc. Data obtained in our laboratory give us the assurance that this process of synthesis of high-octane-number paraffins could be utilized on a commercial scale. The advantages of this method are obvious.

Concerning the alkylation of paraffins by ethylene at very high temperatures and high pressures in the absence of catalysts, this process is possible from the theoretical point of view, since under these conditions the formed radicals are able to inter-react with each other. Recent experiments along these lines carried out by Frey and Hepp[8] indicate that alkylation does take place, but at very high pressure (4500 lbs.).

The results obtained by catalytic and non-catalytic methods of alkylation of paraffins by olefinic hydrocarbons cannot be compared. In the catalytic process, we are the masters of the reaction and can obtain the theoretical yields of paraffins which are suitable for the highest grade of gasoline.

To emphasize further the importance of catalytic methods for the petroleum industry, we can compare the present reforming process for increasing the octane number of gasoline with proposed catalytic methods of auto-destructive alkylation and catalytic isomerization.

Undoubtedly, the reforming process considerably improves the quality of gasoline; but, as with any pyrolysis, it is accompanied by the formation of gases such as methane, ethane, etc., and of other normal paraffins. By merely subjecting hydrocarbons to further pyrolysis, we cannot utilize them as efficiently as by catalytic reactions with other hydrocarbons.

The more delicate method of catalytic destructive alkylation will allow us to treat saturated hydrocarbons in such a way that the gasoline produced will have a high octane number, and the gases will contain a very important hydrocarbon, isobutane, which is highly desirable for alkylation. In the future the by-products of petroleum will be utilized in a more efficient manner, and all waste will be eliminated.

Cracking, which at the present time is applied on such a large scale, will probably be modified by the introduction of catalysis. Since the various hydrocarbons contained in petroleum will require different conditions of time, temperature and pressure, etc., for catalytic decomposition and isomerization, it is probable that selective catalytic cracking will be necessary, starting with specific distillates for each operation.

This article will not discuss the high-boiling petroleum distillates from which lubricating oils are obtained. This branch of the petroleum industry has employed for a number of years the catalytic method of destructive hydrogenation for the purpose of obtaining good lubricating oils from petroleum distillates which otherwise had no application in industry. Also, the catalytic polymerization of olefins to synthetic lubricating oils, by means of active catalysts such as aluminum chloride, is being used.

Nor shall the article review the other catalytic reactions which are indicated in Figure 1 which have been studied in the laboratory of the Universal Oil Products Co. in Riverside, Ill., U. S. A. All these reactions will have, in the future, a great bearing on the petroleum industry, from the point of obtaining desired hydrocarbons and also with the purpose of determining the structures of different types of hydrocarbons.

The information obtained in our laboratory as well as in the research institutes of different countries gives at the present time full confidence that a new catalytic period has begun in the technology of petroleum. In future, all of our attention must be devoted to the introduction of new catalytic methods for the purpose of obtaining different hydrocarbons and for the investigation of structure.

It can be said with assurance that those who are the first to supply the catalytic reactions shown in Figure 1, will be the leaders of the petroleum industry and that they will open new paths towards its rational utilization for the benefit of mankind.

[8] **Frey and Hepp, Ind. Eng. Chem. 28, 1430 (1936).**

PRODUCING AVIATION FUELS

By Pressure Hydrogenation

By C. L. Brown* and E. J. Gohr**

THE GROWING demand for aviation gasolines of superior anti-knock quality can be satisfied only by resorting to newer methods than those currently in vogue. The three prime characteristics of aviation gasoline which must be controlled are: chemical stability, volatility, and anti-knock quality. To meet the requirements of each it is customary to make aviation fuels by distillation of crudes selected for high anti-knock value of the gasoline fraction they contain. The saturated character of such straight-run fuels insures high chemical stability; the volatility is controlled by distillation; and the natural anti-knock value, usually 72 to 75 octane number (C.F.R.-A.S.T.M.), is increased, if desired, by the addition of tetraethyl lead or commercial benzol or toluol. However, natural aviation naphthas of such high octane number (74-75) are relatively scarce, and there is a definite limit to the applicability of either lead or benzol in further increasing their anti-knock characteristics. With the addition of 3 cc. tetraethyl lead per gallon the best natural aviation naphthas rarely reach 90 octane number, and further addition of lead is relatively ineffective. In the case of benzol blending, the tendency of benzol to crystallize at low temperatures limits its use, so that it is not usually practicable to reach much higher than about 80 octane number by benzol addition.

The problem, then, is to supply additional quantities of aviation naphtha, equal in chemical stability and volatility to the natural fuels, and superior in anti-knock quality. Cracking of higher boiling petroleum fractions may be applied to give high octane number and satisfactory volatility, but the chemical stability of the cracked fuel has been held in question. However, hydrogenation is adaptable to the production of aviation gasolines of high octane number as well as satisfactory volatility and stability.

Three distinct hydrogenation processes are applicable: (1) Moderate-temperature hydrogenation of aromatic-type virgin and cracked gas oils and heavy naphthas over newly-developed catalysts; (2) High-temperature aromatizing hydrogenation of similar feed stocks over any of the usual catalysts; (3) Low temperature hydrogenation of highly-branched olefin polymers such as diisobutylene.

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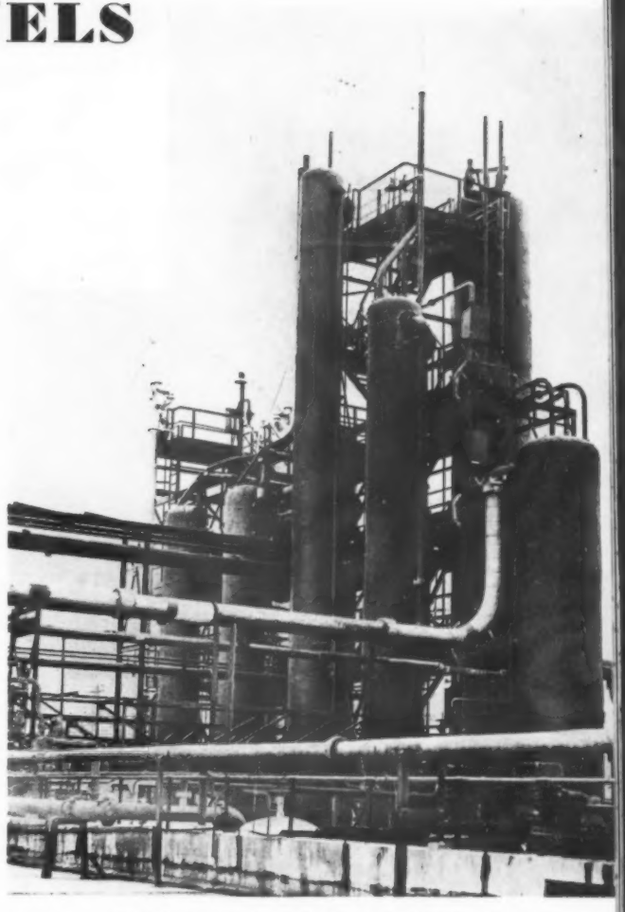
PART I: MODERATE-TEMPERATURE HYDROGENATION OVER NEW CATALYSTS

The moderate-temperature hydrogenation of aromatic type stocks for high octane number aviation gasoline is the latest development of the hydrogenation process, and is made possible by a new type of catalyst which combines high gasoline conversion with a selective dehydrogenation of cycle molecules. The general equipment and flow of materials is practically the same in the various adaptations of high pressure hydrogenation. There have been no basic changes in design of operation since the earlier published presentations of the hydrogenation work in this country. By moderate-temperature hydrogenation over this new catalyst, aviation naphthas of conventional volatility and having A.S.T.M. octane numbers of 75-78 are produced from a variety of feed stocks at conversion rates as high as 60 percent per pass and at ultimate yields of 80-90 percent. It should not be overlooked that these represent yields of gasolines of very high volatilities which will meet by a wide margin the specifications imposed in most countries. If gasolines of lower volatility are prepared the yields will naturally be higher, due both to the fact that smaller quantities of gaseous hydrocarbons are formed and that less drastic stabilization is necessary. In addition use of a feed stock of more suitable boiling range may increase the yields further. The hydrogenated aviation gasolines are characterized by the absence of olefins, low sulfur content, high lead susceptibility, and the gum and color stability inherent to natural naphthas. No finishing is required for these fuels, other than a caustic wash.

The selection of charge stock determines the octane number and the production rate of the hydrogenated naphtha. Virgin heavy naphthas from naphthenic or aromatic crudes are particularly desirable from a standpoint of high octane number and high plant capacity. The feed stock may be run in recycle operation to ultimate yield of aviation gasoline, or alternatively, once through operation may be employed to give in addition to aviation gasoline a bottoms cut consisting of heavy naphtha and light gas oil.



Distillation section of Imperial Chemical Industries Ltd.'s coal and coal tar hydrogenation plant at Billingham, England.

Commercial production of aviation gasoline using moderate-temperature hydrogenation with the latest catalyst is currently under way.

An inspection of the stabilized aviation gasoline produced follows:

A. P. I. Gravity	64
Reid Vapor Pressure, Lbs.	7
Acid Heat, °F	4
Army Gum, mgs./cc	1.2
Sulfur, %	0.01
Color, Saybolt	+30
Corrosion	Pass
Doctor	Pass
Cu. Dish Gum, mg. /100cc	2.0
A. S. T. M. CFR Octane No.	
Clear	76.6
Plus 1cc Pb/Gal.	84.5
" 2 " "	87.0
" 3 " "	88.8
Army Air Corps Octane No.	
Clear	76.8
Plus 1cc Pb/Gal.	87.0
" 3 " "	92.9
" 6 " "	97.5
Series '30 @375 °F Octane No.	
Clear	71.9
Plus 1cc Pb/Gal.	84.1
" 3 " "	88.3
" 6 " "	91.5
A. S. T. M. Distillation	
Initial °F	104
% @ 167°F (75 °C) Dist. +Loss	32.4
% @ 212°F (100°C) " " "	63.9
% @ 257°F (125°F)	95
Final, °F	275
Resudue, %	0.6
Recovery, %	97
Distillation Loss, %	2.4

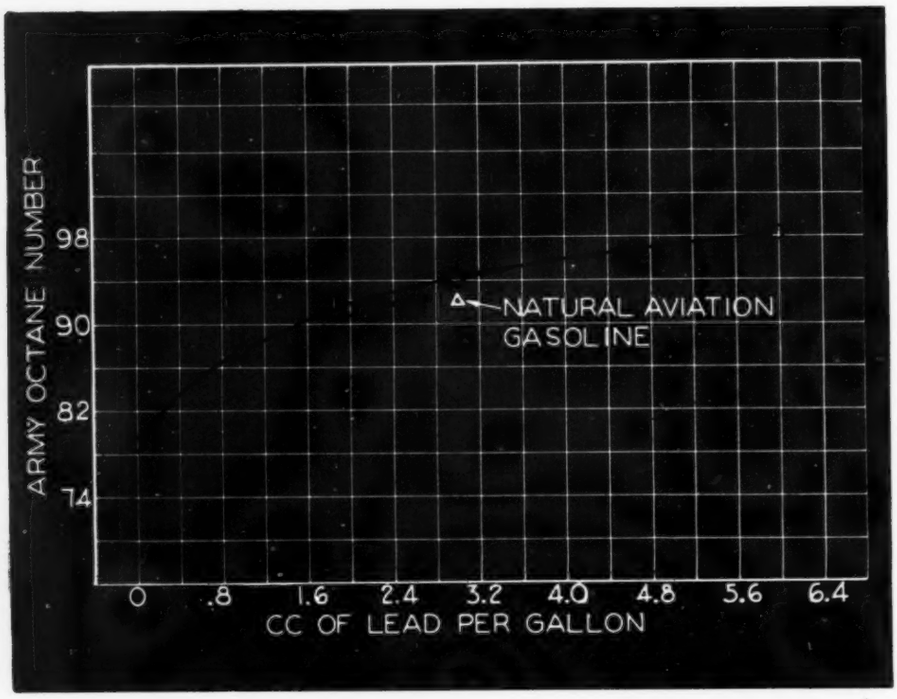


Figure 1.

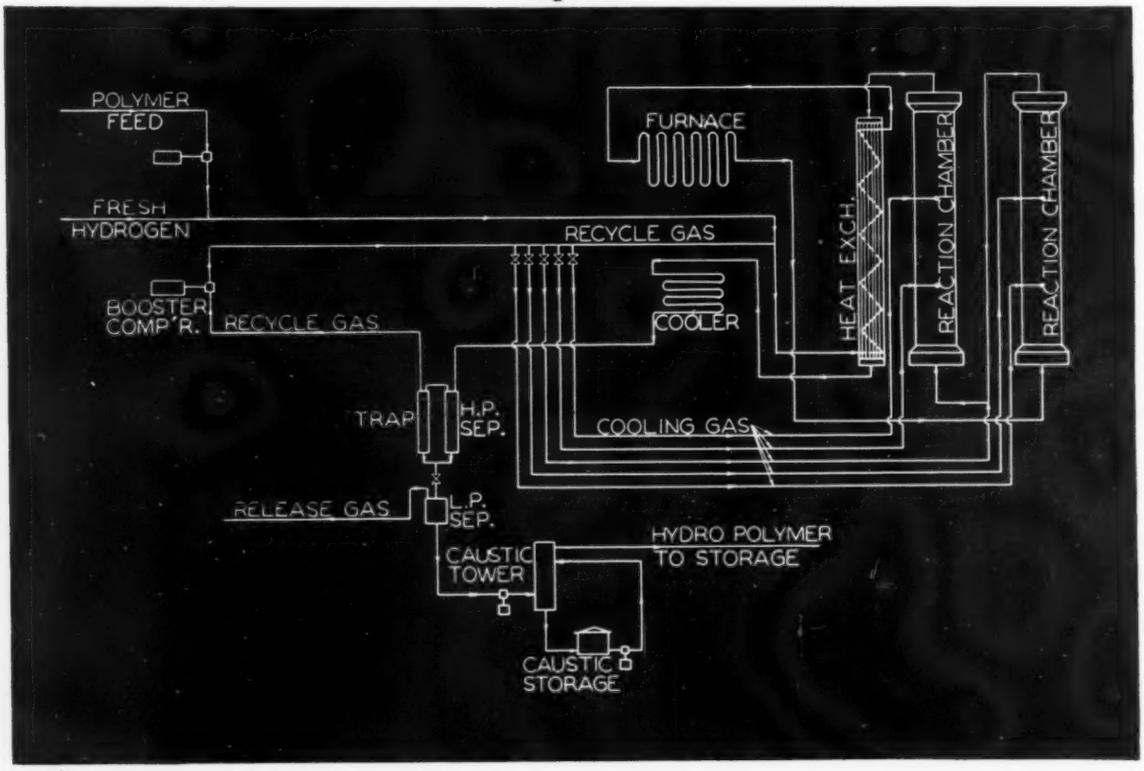
The stabilized aviation gasoline produced possesses high lead susceptibility and requires no finishing except sweetening. Furthermore, it shows high octane number when measured by the Army test as well as the severe Series '30 test at 375 deg. F. jacket temperature.

Typical hydrogenation data obtained in an experimental unit producing approximately one barrel per day of hydrogenated naphtha when charging a virgin heavy naphtha from Coastal crude show a high rate of conversion: 65 percent fresh feed at a total feed rate of two volumes per volume of catalyst per hour. The yield of stabilized aviation gasoline (7 pounds Reid) is 85 percent by volume of fresh feed. This yield is lower than would be obtained in motor gasoline manufacture (upwards of 100 percent) from gas oil charging stocks, both because of the lower gasoline end point and because of the rejection of all butanes to meet vapor pressure specifications.

Inspection data of the hydro gasoline and a typical high-grade natural aviation naphtha show that the two gasolines are of approximately the same volatility, and are quite similar in stability characteristics. Both have negligible unsaturation as indicated by low bromine number and low acid heat; both are exceedingly stable as shown by negligible copper dish gum and long breakdown time. However, the hydrogenated aviation naphtha has the advantage of 3.8 points higher octane number than the natural gasoline (78.3 versus 74.5 A.S.T.M.- C.F.R.).

The octane-number superiority of the hydrogenated fuel over the natural naphtha is largely retained on the addition of tetraethyl lead. Figure 1 presents the lead susceptibility curve of the hydrogenated fuel according to the U. S. Army Air Corps octane number test. It will be noted that this method of rating appreciates the leaded octane number of the hydrogenated naphtha. The Army octane number of the hydro fuel containing 3 cc. of tetraethyl lead per

Figure 2.



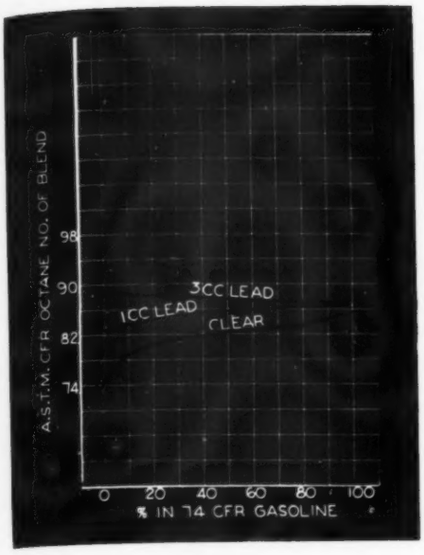


Figure 3.

gallon is somewhat superior to the Army octane number of the similarly rated natural naphtha (94 versus 92). Especially notable and unusual is the appreciable increase in octane number (from 94 to 98) as the lead addition is increased from 3 cc. to 6 cc per gallon.

Because of its high octane number and excellent volatility characteristics, the hydrogenated fuel is ideally adapted to the preparation of the so-called "100 Army" octane number aviation fuel. This super fuel is regularly made by blending commercial isooctane with a light casinghead fraction and with a high-grade natural aviation naphtha, 3 cc. of tetraethyl lead per gallon being added to the blend. The hydrogenated aviation naphtha can be substituted for the natural gasoline, with a consequent reduction in the percentage of commercial isooctane used in the 100 Army blend. Typical inspection data show that all of the usual stringent specifications for volatility and stability are amply met, while the octane number is slightly above 100 by the Army method.

Similar experimental hydrogenation for aviation gasoline has been conducted with a number of charging stocks other than the Coastal naphtha referred to above. Inspections of hydrogenated aviation gasolines produced show high octane number (75.3-76.8) and uniformly good susceptibility to tetraethyl lead. The gasolines all show negligible unsaturation (as indicated by low acid heat) irrespective of whether the charging stock is virgin or cracked.

While the results presented herein for moderate-temperature hydrogenation with a new catalyst are quite striking from the standpoint of octane number of the aviation gasolines, these results are not considered the ultimate obtainable. Laboratory-scale studies in progress on experimental catalysts give promise of further increasing the octane number of the aviation naphtha without sacrifice in yield, conversion per pass or desirable volatility and stability characteristics.

HIGH TEMPERATURE HYDROGENATION

Previous to the development of the new selective catalyst referred to in the previous section, considerable experimental as well as some plant scale data were obtained with the older catalysts on the production of high octane aviation naphthas by high pressure aromatizing hydrogenation at high temperatures. The feed stocks employed included low boiling, cracked and virgin cuts. Inasmuch as the product was desired to be highly aromatic in composition, charging stocks as aromatic as feasible of preparation were chosen. Likewise because of the low end point specification (275-325 deg. F.) of the light naphthas, it was quite desirable that the feed stock be of low boiling range, so that reasonably high percent fresh feed might be maintained. This type of operation resulted in aviation naphthas of excellent aromaticity and anti-knock properties (81-87 A.S.T.M. octane number); and despite the high processing temperature, the fuels so produced were relatively stable, requiring no acid treating for finishing but only the addition of a small quantity of inhibitor.

The aromatic hydro naphthas, while high in octane number, show poor susceptibility to tetra ethyl lead in the A.S.T.M.-C.F.R. test. However, the Army method of octane number determination appreciates this fuel, both clear and leaded, over the A.S.T.M.-C.F.R. method. The octane numbers of individual fractions of these aviation naphthas increase progressively with boiling range.

These hydro naphthas should find ready application wherever the high octane number and other characteristics of aromatic fractions are desired for aviation fuels. However, because of deficient front-end volatility, it is necessary to blend these hydro gasolines with low boiling natural naphthas to meet conventional specifications for aviation gasolines.

PART II: HYDROGENATION OF OLEFIN POLYMERS

The recent availability of isooctane in commercial quantities has permitted the production of aviation fuels of much higher anti-knock properties than was heretofore practicable.

Commercial isooctane is prepared by the hydrogenation of selected polymers of isobutylene, a common constituent of the gases obtained by cracking petroleum products. Such isooctane consists largely of 2, 2, 4 trimethylpentane. Other branched chain octanes can be made by hydrogenating the so-called "copolymers" which are formed by the reaction of isobutylene and normal butylene. These isomeric octanes are quite similar to commercial isooctane, and can be utilized for production of premium fuels in much the same manner.

The hydrogenation step which is so essential in the manufacture of isooctane and its related compounds is described herein as adapted by the Standard Oil Development Company to the manufacture of these materials.

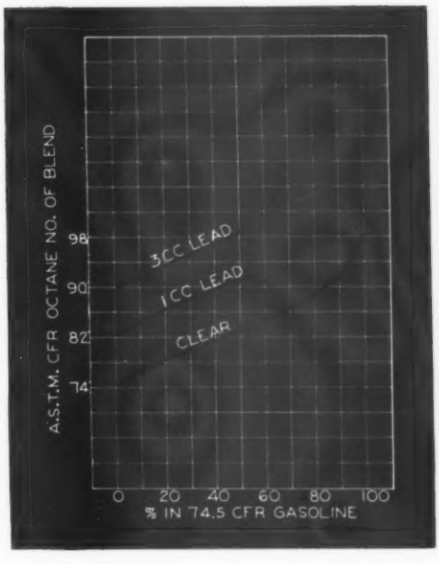
The commercial isooctane and its isomers which are employed in the preparation of high octane number fuels, have a chemical stability equal to that of the best virgin aviation gasolines, since they are completely saturated chemical compounds. They have low sulfur content, low copper-dish gum, excellent color stability, low vapor pressure, and low freezing point. The octane number of commercial isooctane by the C.F.R.-A.S.T.M. method of test is 99 to 100. Inspections of a typical sample of commercial isooctane produced in large quantities by the Standard Oil Development Company are given in the accompanying table.

Inspection Characteristics of Commercial Isooctane

Gravity, A.P.I.	70.8
Color, Saybolt	+30 up
Doctor	Passes
Copper Dish Corrosion	Passes
Copper Dish Gum, Mgs/100 cc	2.6
Bromine Number	0
Reid Vapor Pressure @ 100 deg. F.	3.0 pounds
A.S.T.M. C.F.R. Octane Number	99.5
Breakdown Time (Hours)	24+
A.S.T.M. Distillation:	
Initial °F.	190
5% @	198
10% @	206
30% @	212
50% @	213
70% @	215
90% @	218
95% @	222
Final °F.	245
Recovery %	99.0

Aviation gasoline specifications generally require that 10-30 percent be distilled at

Figure 4.



75 deg. C. (167 deg. F.) to provide front end volatility. Commercial isooctane, it will be noted, does not possess this characteristic but by blending with suitably fractionated natural aviation naphthas a product of wholly satisfactory volatility is obtained. In this manner aviation fuels of 100 octane number by the U. S. Army Air Corps method of test and meeting the conventional aviation gasoline distillation requirements have been produced commercially. These fuels comply in every respect with the specifications for the U. S. Army, the British Air Ministry and the French Air Ministry. The C.F.R.- A.S.T.M. octane numbers of the unleaded fuels are about 83.5. Army octane number 92 can be reached with 0.42 cc. of lead.

The octane number can also be varied by changing the percentage of isooctane in the base blend. For example, fuels of 87 C.F.R. and 77 C.F.R., containing no lead, have been prepared.

As mentioned above, hydrogenated mixed polymers of iso- and normal butylenes can also be used for the production of high antiknock value fuels. Hydrogenated polymers of this type are somewhat higher boiling than commercial isooctane and are somewhat lower in octane number. Their employment in aviation fuels requires a lower boiling base stock and likewise a higher content of hydro polymer. An inspection of an aviation fuel containing hydrogenated co-polymers plus 3 cc. of tetraethyl ead per gallon follows:

A. P. I. Gravity	69.9
Gum, Cu Dish	1.0
Corrosion, Cu Dish	Passes
Doctor	Passes
Color, Saybolt	Blue
Reid Vapor Press. @100°F.	7.0
Acid Heat, °F.	1
Breakdown, Hours	+20
Sulfur, %	0.012
A. S. T. M. CFR OCT. No.	Equal to pure isooctane +0.08cc of lead per gallon.
Army Octane No.	100
Freezing Point, °F, less than	—76
A. S. T. M. Distillation	
Initial	118
% @ 167°F (Dist. +Loss)	25.2
% @ 212°F (Dist. +Loss)	55.2
% @ 257°F	
Final °F	255
Recovery %	98.0
Dist. Loss %	1.2
Sum of 10 and 50% Dist. Temp.	359

COMMERCIAL HYDROGENATION OF POLYMERS

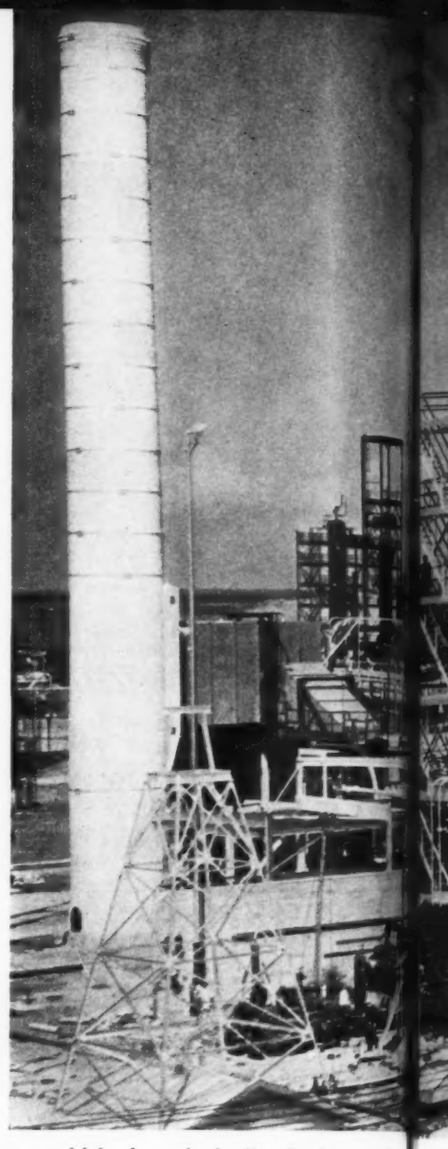
At Baton Rouge, Louisiana, a plant has been hydrogenating diisobutylene commercially for more than a year. A general flow diagram of this plant is shown in Figure 2. The same type of equipment and the same flow of materials are used in polymer hydrogenation as in other adaptations of the high-pressure hydrogenation process for gasoline, kerosene, lubricating oil and solvent production.

The hydrogen for the commercial-scale polymer hydrogenation is obtained by reormation of natural or refinery gas with steam. This is carried out in tubes packed with catalyst heated by direct firing in a radiant type furnace. The gas and the steam passing over this catalyst unite to form carbon monoxide and hydrogen. Following this stage, additional steam is added and the mixture passed over a second catalyst at a lower temperature wherein the carbon monoxide is converted to carbon dioxide and hydrogen according to the water gas reaction. The gas leaving this stage of the process, containing roughly 77 percent of hydrogen, is cooled and conducted to a holder for temporary storage prior to compression.

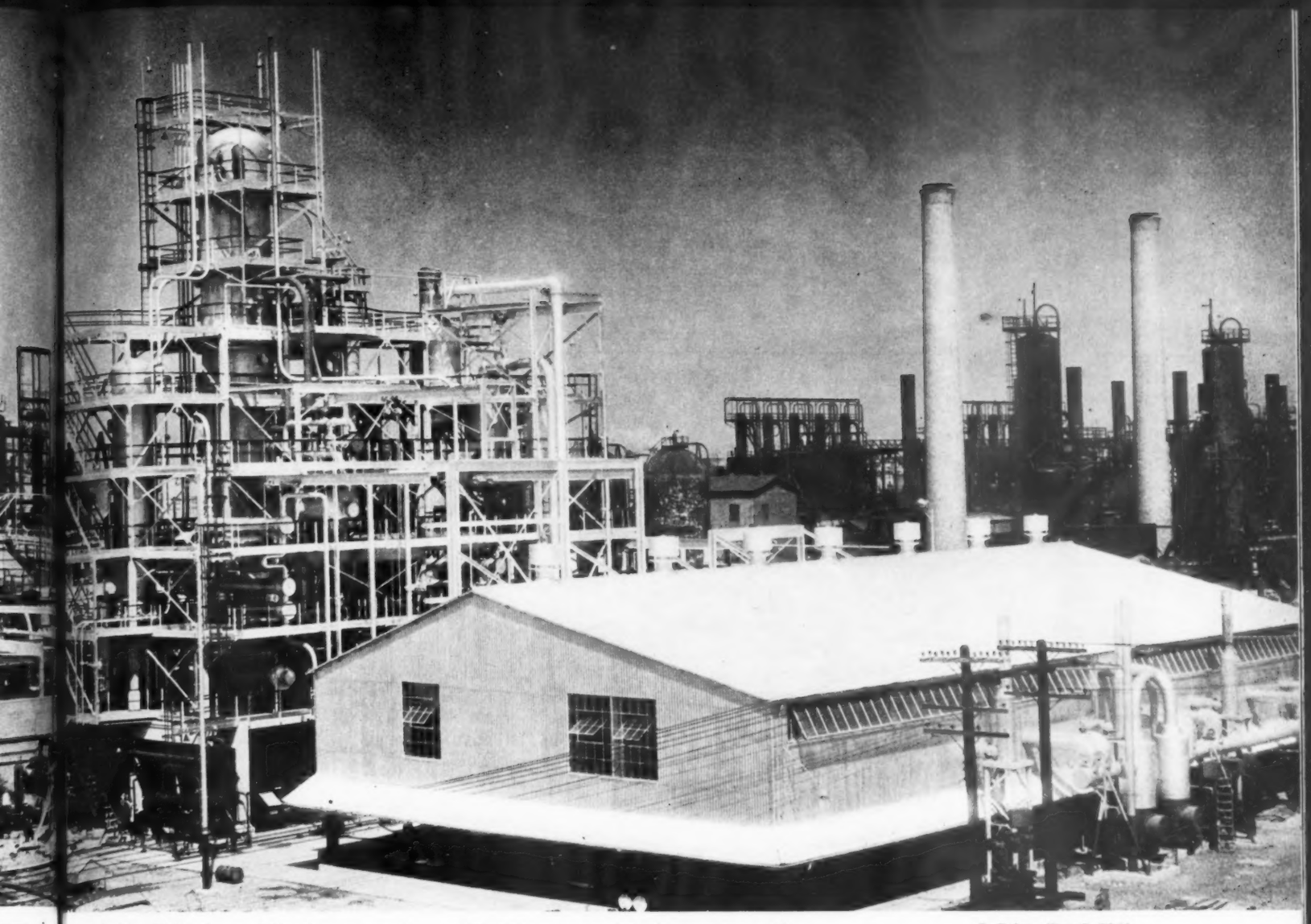
From the holder the gas passes through the compressors where it is compressed in two stages to a pressure of about 250 lb. per sq. in., following which it is conducted to equipment for removal of carbon dioxide. This may be carried out by scrubbing with water or with suitable chemical solvents. The scrubbed gas leaving this equipment contains approximately 95 percent hydrogen and is returned to the remaining stages of the compressors wherein it is raised to a pressure of about 3,000 lb. per sq. in.

The liquid polymer is raised to the operating pressure by steam driven pumps. The mixture of liquid polymer, fresh hydrogen and recycle hydrogen (returned from the hydrogenating system), all at about 3,000 lb. per sq. in., is delivered to a heat exchanger where the mixture is preheated by the hot hydrogenated products coming from the reaction chamber. Additional heat is then supplied in a tube furnace wherein the temperature is raised to that required for reaction. The oil and gas mixture then flows from the fired coil to the first reaction chamber, which is filled with a sulfur-resistant hydrogenation catalyst. Because of the exothermic nature of the hydrogenation reaction, considerable heat is evolved and arrangements must be made to cool the mixture below the temperature at which cracking might occur. The chamber is therefore equipped with gas nozzles at different points in the catalyst bed to afford admission of cool recycle gas for maintaining the proper temperature.

On leaving the first reaction chamber the mixture of hydrogen and partially hydrogenated polymer passes into a second catalyst chamber identical with the first. As in the first chamber, the hydrogenation reaction proceeds at temperatures controlled by admission of cold gas in the cooling nozzles. Hydrogenation is completed in the second chamber. The mixture of hydrogenated polymer and hydrogen leaving the second chamber is heat-exchanged with the entering feed mixture, and then cooled in a tubular water cooler. The cold products pass to a high-pressure separator where a gas and liquid separation is made. The



gas, which is principally hydrogen, is picked up by a booster-compressor, and recycled to the system both as cooling gas and as recycle gas added to the incoming feed. The liquid product is stepped down to atmospheric pressure following the high-pressure separator, whereupon a certain amount of dissolved gas is released from the liquid. The liquid and gas are separated in a low-pressure separator, the gas being sent to a fuel gas line. Depending on the nature of the operation, the type of product desired and the character of the polymer being hydrogenated, the liquid may be submitted to stabilization to remove a small percentage of isobutane and butane formed in the hydrogenation process as a product of cracking due to some local overheating. The stabilization also removes some hydrogen sulfide formed by the hydrogenation of organic sulfur compounds contained in the feed stock. If this sulfide were not removed, it would subsequently be oxidized to free-sulfur and the feed would fail to pass the corrosion test. In case the stabilization step is not employed, the hydrogenated polymer is immediately pumped to a caustic soda scrubber where it is washed countercurrently with a 10 percent caustic



© Robert Yarnall Richie.

Humble Oil's Baytown refinery, showing the thermal polymerization unit.

solution. Following stabilization or caustic treatment, the material is pumped to storage and is ready for use.

Since the catalysts used are highly resistant to poisoning, and since polymer hydrogenation is carried out at a relatively low temperature, long catalyst life is obtained. The Baton Rouge plant is now operating on a batch of catalyst having more than 5,500 hours service. This catalyst still has high activity and it is expected will be suitable for a full year's service. By virtue of this sustained activity, continuous runs of one year's duration are possible.

LABORATORY SCALE POLYMER HYDROGENATION

In preparation for and concurrent with the commercial scale hydrogenation of polymers, the Standard Oil Development Company has pursued experimental hydrogenation work in laboratory scale equipment permitting continuous operation. Studies have been made of several types of polymers and of several catalysts. The conditions for operation during hydrogenation were substantially the same for all polymers over any given catalyst.

The laboratory-scale hydrogenation, with continuous operation, has been carried out in small units duplicating the large plants. Heat exchange is not employed on the small scale, the oil and hydrogen mixtures being brought to reaction temperature in a small coil immersed in a heated lead bath. The light gas, principally hydrogen, released in the liquid-gas separator, can be recycled to the unit in order to furnish information on the effect of returning the gas on ultimate yields.

The characteristics of some of the various polymers before and after hydrogenation are compared in the following discussion. The products of most of the current polymerization processes have been hydrogenated, these including (a) commercial diisobutylene, (b) triisobutylene, (c) co-polymers of iso- and normal butylenes, (d) mixed polymers of propylenes and butylenes, and (e) polymers produced by thermal polymerization.

Commercial Diisobutylene

The feed stock termed "commercial diisobutylene" is a product consisting largely of diisobutylene together with small amounts of the polymers of iso- and normal butylene and a small percentage of butanes, butylenes and triisobutylene. Upon hydrogenation the commercial diisobutylene produces commercial isooctane.

The hydrogenated material is completely saturated and shows substantially the same boiling range as the feed sock. The extent of hydrogenation, as measured by the acid heat or the bromine number of the hydrogenated product can be controlled between complete saturation and any desired degree of unsaturation.

The hydrogenation of diisobutylene becomes of significance as the octane number of the material is increased from about 84 to 99-100. Furthermore, the response to tetraethyl lead is markedly higher.

The yields obtained upon hydrogenating diisobutylene range from 90 to 103 percent (volumetric) depending primarily upon the catalyst, the type of equipment and the extent of temperature control.

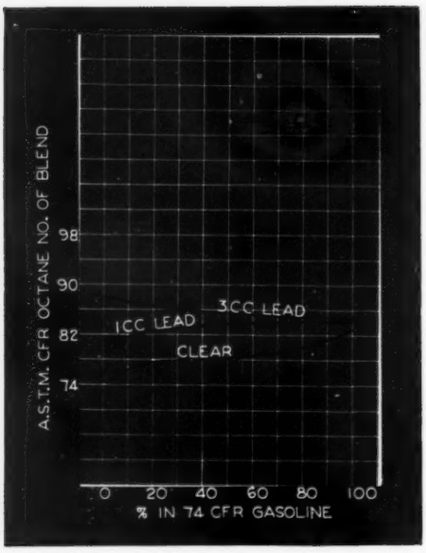


Figure 5.

Commercial Triisobutylene

The production of diisobutylene by polymerization is accompanied by the simultaneous production of limited amounts of triisobutylene and of traces of higher polymers. Experimental hydrogenation has been done on a triisobulylene fraction obtained by distillation of a total polymerization product.

The comparative inspections of triisobutylene and the hydrogenated material indicate that partial decomposition of the trimer has occurred giving rise to isobutane and isooctane in the hydrogenated product.

Diisobutlyene-Triisobutylene Mixtures

Experimental hydrogenation has been carried out on a mixture of diisobutylene and about 40 percent triisobutylene. The distillation indicates that the triisobutylene has experienced partial decomposition and has given lower boiling products. As would be expected, the octane number of the hydrogenated material is higher than that of the base stock, 98 C.F.R. versus approximately 86.

Co-Polymers of Iso- and Normal Butylene

The polymerization of unsaturated gases can be conducted so as to give a product consisting largely of isobutylene polymers or the product can be made to consist of co-polymers made by the union of normal butylene and iso-butylene with yields of the same magnitude. As in the case of diisobutylene, hydrogenation produces a highly stable non-corrosive product of good color. The octane number of the hydro co-polymer is 94 C.F.R. versus 98 for the hydrogenated diisobutylene-triisobutylene mixture but may vary from 90 to 96-97 C.F.R., depending upon the composition of the original co-polymer.

Mixed Polymers of Propylene and Butylenes

A limited amount of experimental hydrogenation has been carried out on a polymer which was produced by a random (non-selective) polymerization of propylene and butylenes. The octane number of the material boiling up to 325 deg. F. showed a marked drop upon hydrogenation. The original polymer (initial to 325 deg. F. fraction) had an octane number of 82 C.F.R. while the octane number of the hydrogenated material dropped to 64.2 C.F.R. This decrease in octane number is believed to result from the saturation of the large amount of straight chain olefins to which the high octane number of the original polymer is probably due.

Thermal Polymerization

A polymer made by pyrolysis and polymerization at relatively high temperature and high pressure was subjected to catalytic hydrogenation. This type of polymer also loses octane number on hydrogenation, dropping from 80 C.F.R. on the original unsaturated material to 62 on the hydrogenated product.

Blending Value

The major and very important advantages resulting from hydrogenation of commercial diisobutylene and co-polymers are the higher octane numbers, the improved lead susceptibility and the greater chemical stability thus obtained. Blends of these hydrogenated polymers and natural naphthas can be made which have anti-knock values superior to any possible from the original unhydrogenated polymers, even with a higher tetraethyl lead content.

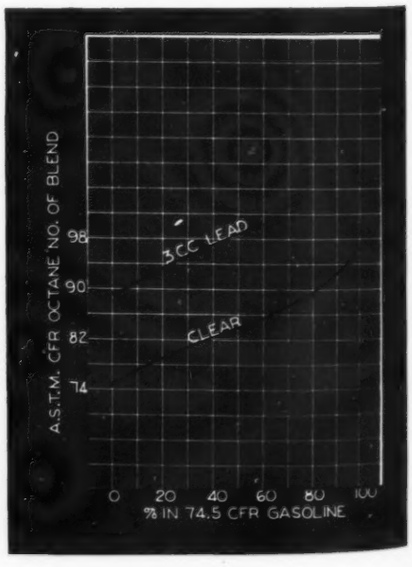
The advantage of hydrogenated diisobutylene for high octane numbers becomes more apparent when preparing leaded blends with natural naphthas. Figures 3 and 4 display the results of adding tetraethyl lead to blends of diisobutylene and of commercial isooctane respectively. An 83 O.N. blend containing about 50 percent of diisobutylene is increased to 86 O.N. with the addition of one cubic centimeter of lead fluid and to approximately 87 O.N. on addition of two more cubic centimeters of lead. However, an 83 O.N. blend containing 45 percent commercial isooctane is increased to 91 O.N. with one cubic centimeter of lead and to 98 O.N. with two more. The maximum octane number with three cubic centimeters of lead is obtained with no diisobutylene present and the polymer addition thus becomes a disadvantage. With commercial isooctane, however, the addition of three cubic centimeters brings a marked octane number increase at all concentrations. It is thus possible to produce blends of 100 O.N. and above from a natural naphtha by a combination of commercial isooctane and lead.

A comparison of the octane number blending values and lead susceptibilities of co-polymers and hydrogenated co-polymers likewise show an advantage for the hydrogenated material in producing higher octane number blends. The hydrogenated material is superior in blending octane number value at all concentrations and octane numbers can be obtained which are beyond those possible from codimer blends. Figures 5 and 6 display the lead susceptibility of blends of codimer and of hydrogenated codimer. As may also be observed in the figures octane number of co-polymer blends with three cubic centimeters of lead is in the range of 88 or below while hydro co-polymer can be used for leaded blends of 100 O. N. or above.

Not only does hydrogenation lower the octane number of the mixed propylene and butylene polymers and of thermal polymers, but higher octane number blends can be obtained at all given concentrations from these polymers in the original state. Furthermore, although hydrogenation improves the lead susceptibility of these polymers, the base octane number of the hydrogenated materials is sufficiently lower than the original polymer as largely to offset the improved lead response. The above relations are illustrated by the following blends:

	Octane Number Untreated	A.S.T.M. CFR With 3 cc. Pb
Aviation Naphtha	74.0	88.5 CFR
Aviation Naphtha Plus 25% Thermal Polymer	75.0	85.5 CFR
Aviation Naphtha Plus 25% Hydrog. Thermal Polymer	71.5	87 CFR

Figure 6.



HEATING OILS Reach "Superior-Use Product" Class

Nineteen Million Barrel Heating Oil Demand Probable by February, 1938, Necessitating Greatly Increased Crude Runs or Lower Yields of Gasoline in Favor of Higher Recovery of Fuel Oil From Crude.

Table 1.—Average Prices of Two Selected Grades of Heating Oils, 1934-1937

(Cents per gallon)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1934													
No. 1 straw oil at Oklahoma refineries	3.11	2.90	2.71	2.87	2.77	1.77	2.47	2.52	2.74	1.88	3.02	3.19	2.66
No. 2 furnace oil, f. o. b. tank car at New York harbor	4.48	4.53	4.63	4.63	4.78	5.00	5.00	4.91	4.81	4.50	4.50	4.68	4.70
1935													
No. 1 straw oil at Oklahoma refineries	3.23	3.13	3.08	3.04	3.45	3.34	3.05	3.02	3.06	3.05	3.05	3.19	3.14
No. 2 furnace oil, f. o. b. tank car at New York harbor	4.75	4.66	4.38	4.18	4.13	4.00	4.00	4.00	4.00	4.00	4.13	4.25	4.20
1936													
No. 1 straw oil at Oklahoma refineries	3.31	3.44	3.49	3.59	3.55	3.31	3.11	2.93	2.98	3.11	3.33	3.53	3.31
No. 2 furnace oil, f. o. b. tank car at New York harbor	4.38	4.69	4.69	4.41	4.25	4.25	4.25	4.21	4.19	4.30	4.25	4.38	4.35
1937													
No. 1 straw oil at Oklahoma refineries	3.65	3.97	3.94	3.81	3.80	3.75	3.75	3.75	3.80				
No. 2 furnace oil, f. o. b. tank car at New York harbor	4.64	4.67	4.51	4.50	4.86	5.17	5.25	5.25	5.25				

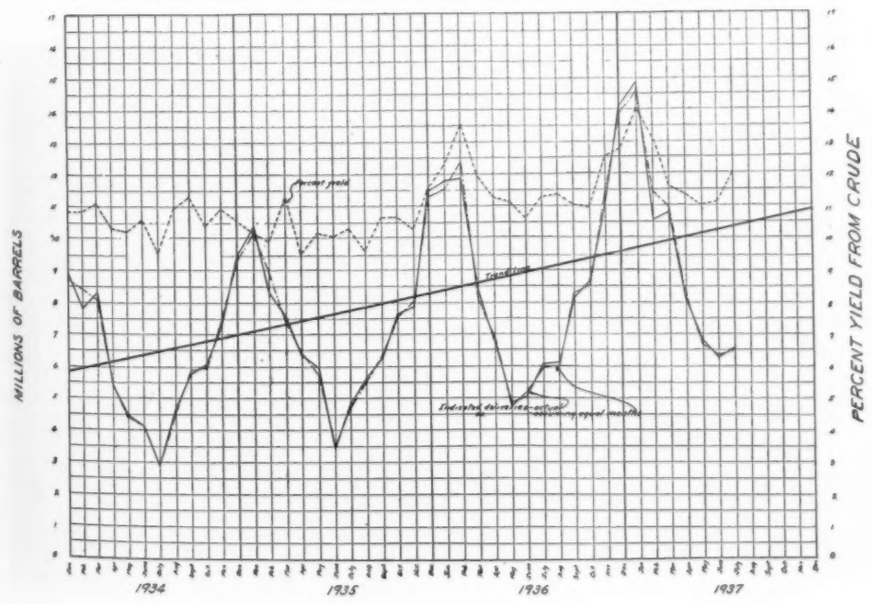
REFINERY engineers are paying more attention to economics, whether they know it or not. Prior to 1935, the job of the average refinery engineer seemed reasonably clear cut; primarily, it involved obtaining the highest yield of gasoline consistent with quality. At odd times he made sure his lubricating oil was superior to his competitors', and experimented with still gases. These assignments were largely techinical; economics was hardly more than an academic term.

In 1935 and 1936 fuel oil, long considered a has-been, staged a comeback in the form of heating oils. The demand for these light fuel oils increased about 25 percent in 1935 over 1934; in 1936, at least that much over 1935. These increases were too phenomenal to be overlooked, even though the demand for gasoline was increasing nearly 10 percent annually.

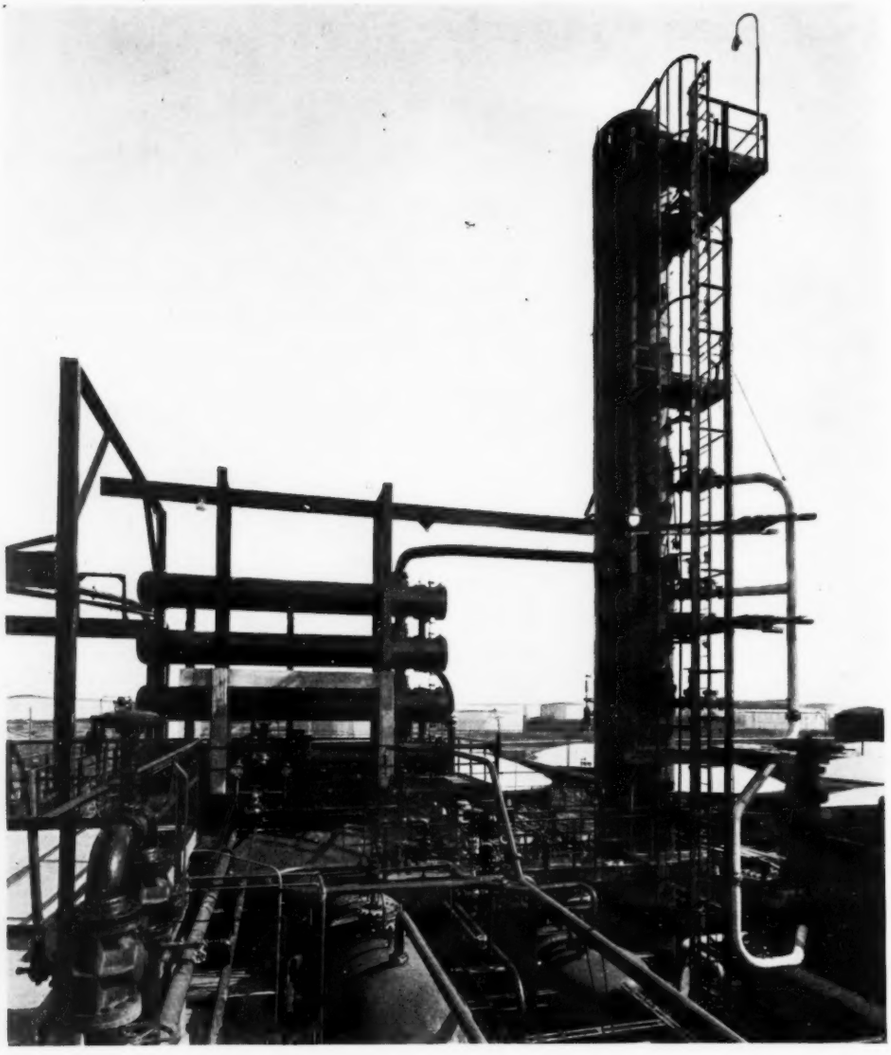
The gain in gasoline demand was met in the main by increased runs to stills. The rise in the demand for heating oil was too great to be met in any such conventional manner, hence it was necessary to adjust the yields of products, that is, raise the heating-oil yield at the expense of gasoline and other products. In accomplishing this the refinery engineer found himself spending an increasing amount of time with prosaic statistics of sales and stocks of gasoline and fuel oil.

Technically, the meeting of 20-25 percent gains in heating-oil demand has never worried the refinery engineer greatly. The average gravity of heating oils is not far from the average gravity of crude oil (about 34 deg.); in fact, some crudes are used in domestic burners without refining. Economically, the situation was somewhat different as up until the spring of 1937 heating oil prices were just about on the edge of profitable operations. The 1937 advance of a cent or more, shown in Table 1, above, did much to increase the popularity of heating oils around the refineries, without causing more than a handful of burner owners to go back to coal. Before the price increase, it was not considered desirable to allow the increasing burner-oil demand to influence gasoline yields—that would be a backward step in conservation! Before the price increase, the supply of burner oils was to be augmented at the expense of residual fuel oil; now refiners are not loath to cut into the cracked gasoline yield for this purpose. In general, reduced cracking lowers the octane, but that can't happen if the refiners are to hold their sales' position, hence the refinery engineer is faced with the necessity of readjusting his crude supplies and operations, or, as a last resort, purchasing tetraethyl lead.

CHART I-TRENDS IN DELIVERIES AND YIELDS OF GAS OIL AND DISTILLATES



What are these heating oils or burning oils or distillates, which threaten even the supremacy of gasoline? How may they be defined? These questions are not simple to answer as no two crudes yield exactly the same products. Roughly, these products cover all the distillates coming off after kerosene, yet some oil burners operate on kerosene or its twin brother, range oil, and some can handle heavy residuals. Based on pure specifications, gas oil and diesel oil are within the group, and oftentimes oils made for gas carburetion or for use in Diesel motors find their way into oil burners. Gravity used to be about the only specifica-



New Lummus combination unit at Pure Oil Company's Smith's Bluff refinery, Texas.

Table 2.—Detailed Requirements for Fuel Oils [1]

Grade [2]	Flash point °F.		Pour point °F.	Water and sediment, per cent	Carbon residue, per cent	Ash, per cent	Distillation temperatures °F				Viscosity, seconds			
							10 per cent point	90 per cent point		End point	Saybolt Universal (at 100°F.)		Saybolt Furol (at 122 °F.)	
	Min.	Max.	Max.	Max.	Max.	Max.	Max.	Max.	Min.	Max.	Max.	Min.	Max.	Min.
No. 1. A distillate oil for use in burners requiring a volatile fuel	100 or legal	165	[3]15	0.05	([4])	....	420	....	....	590	....	....	....	....
No. 2. A distillate oil for use in burners requiring a moderately volatile fuel	110 or legal	190	[3]15	0.05	([4])	....	440	600	....	....	590	....	....	....
No. 3. A distillate oil for use in burners requiring a low-viscosity fuel	110 or legal	230	[3]20	0.1	0.15	....	....	....	[5]600	....	....	55	....	....
No. 4. An oil for use in burners requiring low-viscosity fuel	130	....	....	1.0	....	0.1	....	....	....	....	....	250	55	....
No. 5. An oil for use in burners equipped with preheaters permitting a medium-viscosity fuel	150	....	....	1.0	....	0.15	....	....	....	....	....	....	250	100
No. 6. An oil for use in burners equipped with preheaters permitting a high-viscosity fuel	150	....	....	[6]2.0	....	....	....	....	....	....	....	....	300	[7]100

[1] Recognizing the necessity for low sulfur fuel oils used in connection with heat-treatment, non-ferrous-metal, glass and ceramic furnaces and other special uses, a sulfur requirement may be specified in accordance with the following table:

Grade of fuel oil	Sulfur, max. percent
No. 1	0.5
No. 2	0.5
No. 3	0.75
No. 4	1.25
No. 5	No limit
No. 6	No limit

Other sulfur limits may be specified only by mutual agreement between the buyer and seller.

[2] It is the intent of these classifications that failure to meet any requirement of a given grade does not automatically place an oil in the next lower grade unless in fact it meets all requirements of the lower grade.

[3] Lower or higher pour points may be specified whenever required by conditions of storage or use. However, these specifications shall not require a pour point lower than 0°F. under any conditions.

[4] 0.12 percent on 10 percent bottoms.

[5] This requirement shall be waived when the carbon residue is more than 0.07 percent and less than 0.15 percent.

[6] Water by distillation, plus sediment by extraction. Sum, maximum 2.0 percent. A deduction in quantity shall be made for all water and sediment in excess of 1.0 percent.

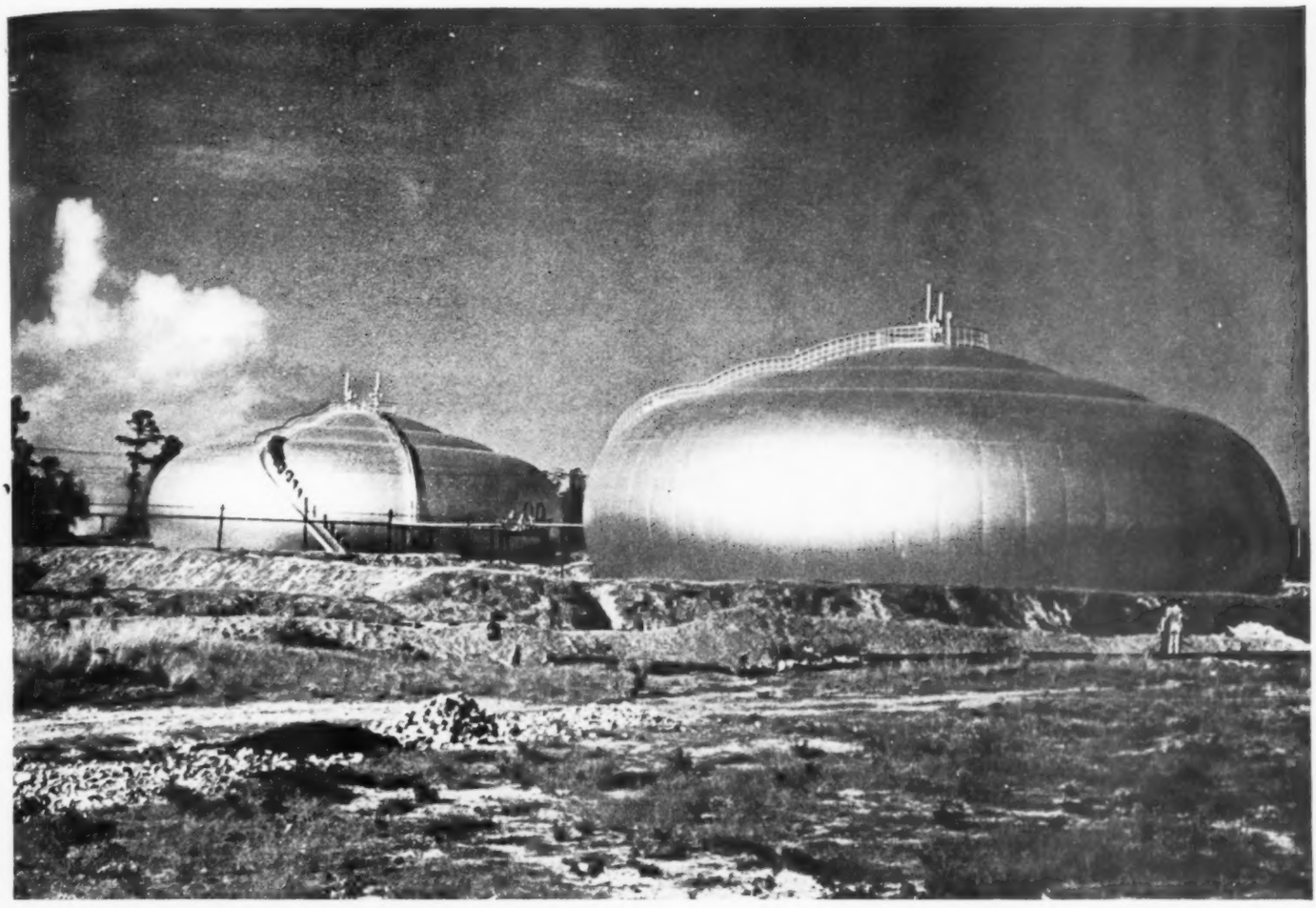
[7] This requirement shall be waived when the carbon residue is 6 percent or more.

tion; now one hears more about viscosity than about relative weight. The confusion resulting from introcuding so many kinds of oil to various types of burners finally became so great that refiners, distributors, consumers, and manufacturers of oil burners got together with the Bureau of Standards and drew up a set of specifications for fuel oils. According to these specifications, which are shown in the following table, fuel oils are divided into six classes, numbered one to six. In general, the lower the number, the lower the viscosity and the higher the gravity, although, as previously indicated, a No. 2 fuel oil from one crude may be heavier than a No. 3 from another.

As with gasoline specifications, the foregoing limits for fuel oil are not rigidly followed by the companies. Most companies probably use them as starting points in establishing their own specifications to meet their customers' needs. The average customer knows little and cares less about the flash point, viscosity, etc., of his fuel oil and how they are obtained at the refineries.

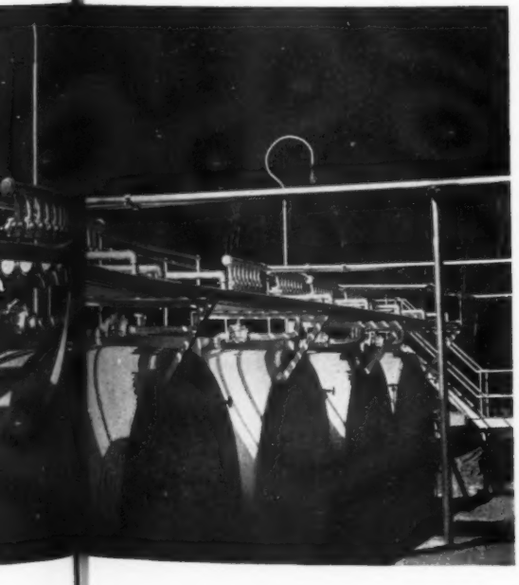
Although the available statistics on fuel-oil consumption are improving rapidly, they are as yet inadequate in measuring the growth in heating oil demand. Within the last year the U. S. Bureau of Mines has made available monthly data on the indicated domestic demand for gas oil and distillate fuel oils. Beginning in 1926 that Bureau began annual surveys of fuel-oil consumption by states and major uses. Pertinent data from these two statistical series are given in Table 3 and Chart 1, which follow.

The most striking fact revealed in Table



Two 80,000 bbl. spheroid storage tanks at Humble Oil's Baytown thermal polymerization plant.

Continuous treating tanks at the Cabin Creek refinery of Pure Oil Company.



3 is, of course, the large percentage gains in indicated deliveries of gas oil and fuel oil as a group and in sales of both heating oils and range oils. Range oil is generally classed with kerosene rather than with heating oils, but the consumption data for it are too imposing to be ignored in any discussion of fuel-oil demand. Another important aspect of Table 3 is the increase in yield since 1930. This may seem small in percent of yield but on a hundred million barrels of crude oil as now refined each month it represents a considerable output. Note in Chart 1 the rapid rise in yields in the winter months of 1936 and 1937. Before that the refiners apparently made little effort to adjust their operations to meet the heating-oil demand. Imports of gas oil and distillate fuels, which apparently began in 1934, have never been important. On the other hand, exports have comprised a material part of the total demand and the 60 percent gain indicated for 1937 over 1936 in shipments abroad is an element to be reckoned with in supplying the demand for the heating season just underway.

Of the indicated deliveries of gas oil and distillate fuel oils (103,462,000 bbl. in 1936)

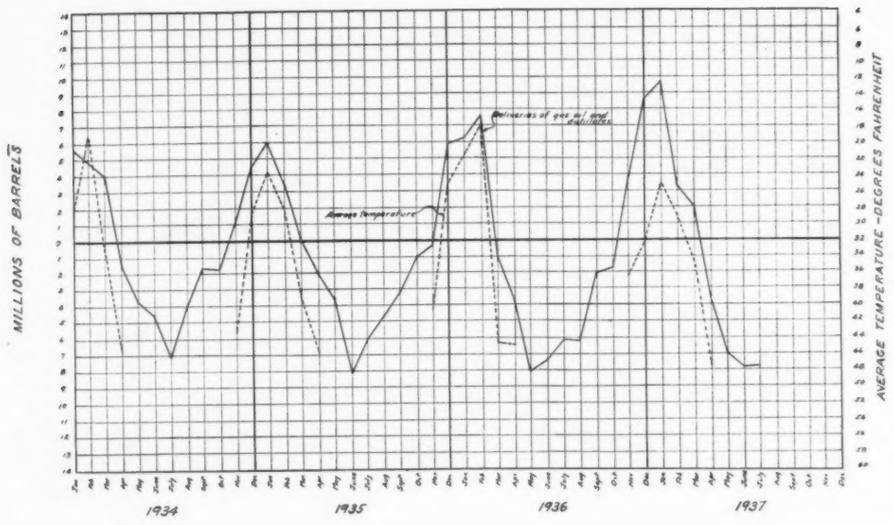
Table 3.—Salient Statistics of Light Fuel Oils, 1930-1937

(Thousands of barrels)

Year	Production	Percent yield	Imports	Exports	Stocks at refineries end of period[1]	Indicated deliveries	Percent increase over previous period	Sales of heating oils	Percent increase over previous year	Sales of range oil	Percent increase over previous year
1930	81,551	8.8	.....	[2]13,000	16,390	68,939	.....	43,279	.....	3,000	.....
1931	83,882	9.4	.....	[2]11,000	18,526	70,746	3	40,578	[3]6	4,549	52
1932	69,467	8.5	.....	8,782	14,110	65,101	[3]8	44,264	9	6,841	50
1933	78,920	9.2	.....	11,424	[4]14,277 17,025 [4]16,315	64,581	[3]1	50,140	13	10,269	50
1934	94,972	10.6	3	14,131	21,957	75,202	16	60,822	21	15,756	53
1935	100,235	10.4	15	16,249	19,930	86,028	14	76,853	26	21,526	37
1936	125,650	11.8	485	19,884	22,719	103,462	17	[2]97,000	26	[2]27,000	25
1937-(Jan.-July)	81,104	12.1	556	16,628	23,637	64,114	16	.....	.....	.....	.....
1937[2]	153,000	13.0	1,000	30,000	22,000	125,000	20	.....	.....	.....	.....

[1]Stocks at end of 1929—16,778,000 barrels
[2]Estimated
[3]Decrease
[4]New basis

CHART II—RELATIONSHIP OF FUEL-OIL DEMAND TO TEMPERATURE



about three-fourths are heating oils for domestic burners, most of the remaining fourth being diesel oil. Data on the number of oil burners in use and the average concumption per burner are shown in the following Table 4.

According to Table 4, the late depression failed to prevent sizeable increases in number of burners, but may have had something to do with the decrease in oil consumption in 1931. Since 1931 the average consumption per burner has increased steadily, reflecting to a degree the fuller purse or less need for economy, but mainly an increase in the average size of installations.

So much for the past—what of the future? What will the heating-oil demand be this winter? Will the refiners meet the anticipated increase? Is there any danger of a shortage in case the weather is as severe as in the winter of 1935-1936? The answers to questions two and three are simple compared with that of the first.

The prolongation of the heavy trend line in Chart I gives the indicated domestic demand for gas oil and distillate fuel oil in 1937 as 125,000,000 bbl., or 20 percent higher than in 1936. But that was too simple—how high will the monthly demand figures go if the weather is mild like last year or cold as it was the year before? These additional questions suggested the preparation of Chart II, which follows.

Table 4.—Number of Domestic Oil Burners and Consumption per Burner

Year	Average number of domestic burners in use[1]	Estimated consumption of of heating oils in domestic burners (barrels).	Average consumption per burner (barrels)
1930..	606,300	25,771,000	43
1931..	712,900	24,847,000	35
1932..	802,000	27,886,000	35
1933..	881,800	32,591,000	37
1934..	967,200	41,359,000	43
1935..	1,084,400	54,566,000	50
1936..	1,253,700	72,000,000	57
1937..	1,500,000	90,000,000	60

1930-1936 from A. P. I.; 1937 estimated.

In Chart II the same monthly figures of gas oil and fuel oil deliveries as shown in Chart I have been plotted above the trend line, which has been rotated to form a normal at O. This procedure was followed principally to eliminate the growth in consumption due to the increasing number of installations. Superimposed on this, in reverse scale, are temperature curves for the heating seasons of 1934-1937. The temperatures indicated are the averages weighted according to fuel-oil consumption by states. As an additional refinement the monthly figures of demand have been smoothed out over twelve months of equal length.

Probably this chart's outstanding claim to credit is that with one exception (February, 1934) it shows consumption going up when the temperature goes down, and vice versa. Q. E. D.! As regards the matter of how much consumption rises per degree decline in temperature, the chart is deficient, if not misleading. It shows demand in the early months of 1937 rising well above the temperature line, whereas in February, 1936, when the average temperature was only 18 deg. F., the two lines are close together. This behavior apparently confirms the oft-expressed belief that, although it takes relatively much more oil to heat a house on a very cold day, it takes comparatively little more during a cold season. It also indicates that economic conditions have at least as much to do with oil consumption as temperature. It is too bad that Chart II developed as it did as, otherwise, all one would have to do would be to measure the hair on the rabbits or the bark on the trees to forecast the demand.

Returning to the problem of the demand for heating oils during the present season, it was estimated above that the demand for the calendar year 1937 would be about 125,000,000 bbl. Of this, November could claim 12,500,000 bbl. and December 15,500,000 bbl. Refinery stocks of gas oil and distillate fuel oils east of California were considered to have reached rock bottom levels early in 1936 at around 15,000,000 bbl. This figure includes an excess in California, but as demand has grown and more working stocks are needed east of California, it may be used as the estimated low point for 1938. An approximate picture of supply and demand for the six months, November, 1937, to April, 1938, may then be drawn as indicated in Table 5.

The yields required to meet the production indicated in this table depend on still another unknown, crude runs to stills. Crude runs to stills used to decline in winter but now that the heating-oil demand has grown to offset the decline in gasoline consumption, runs are practically uniform from month to month. Assuming then that present runs of about 3,400,000 bbl. daily will be maintained during this winter, the highest yield that will have to be obtained is 17.9 percent in February, 1938. That is nearly four percent above the highest yield ever recorded (14.1 in January, 1937), suggesting either that crude runs will have to be raised considerably above the 3,400,000-bbl. level, or that the yields of gasoline and other products will have to be extensively raided in favor of heating oils. In addition is the problem of increasing kerosene yields to take care of the rapid gain in range-oil consumption. Just what adjustments in yields will be made is not clear but probably those for gasoline, residual fuel oil, asphalt, and road oil will decline from present levels. It is virtually certain that the gasoline yield for February, 1938, will not match the 45.0 percent registered last February.

The forecasts of heating oil demand given above presuppose a season of normal temperature. The actual domestic demand for gas oil and distillates might well exceed the 17,000,000-bbl. mark (the top line in Chart I) in the early part of 1938 if the winter is severe. Such an eventuality would require even higher yields from crude. However, now that the average refiner is making money on his heating oils, he is quite willing to alter his operations in favor of a second superior-use product.

Table 5.—Six Months Supply and Demand Forecast

(Thousands of Barrels)

	Demand[1]	Stocks, end of month	Production
November, 1937.....	15,000	25,000	15,000
December, "	18,500	21,500	15,000
January, 1938.....	19,500	19,000	17,000
February, "	19,000	17,000	17,000
March, "	14,000	15,000	12,000
April, "	11,000	16,000	12,000

[1] Including exports, imports negligible.

SYNTHETIC Petroleum and Economic Autarchy

By Dr. O. W. Willcox

Despite Higher Costs, Use of Synthetic Fuels Is Considered Desirable and Substitution of Synthetic for Natural Products May Become a Dominant Factor in the Oil Supply Situation of Certain Nations.

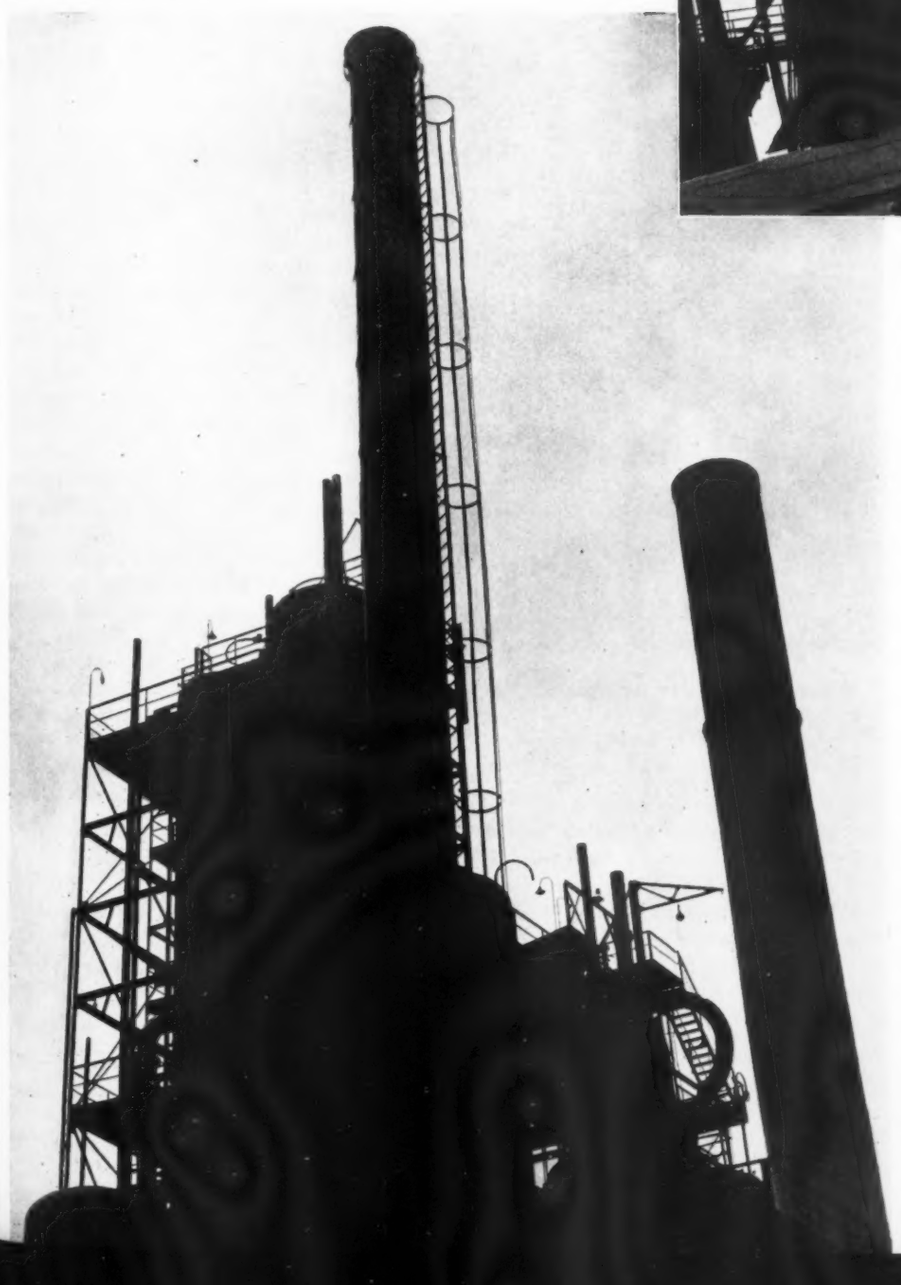
© Standard Oil Company of Indiana

Photograph by Robert Yarnall Richie, courtesy The Texas Corp.

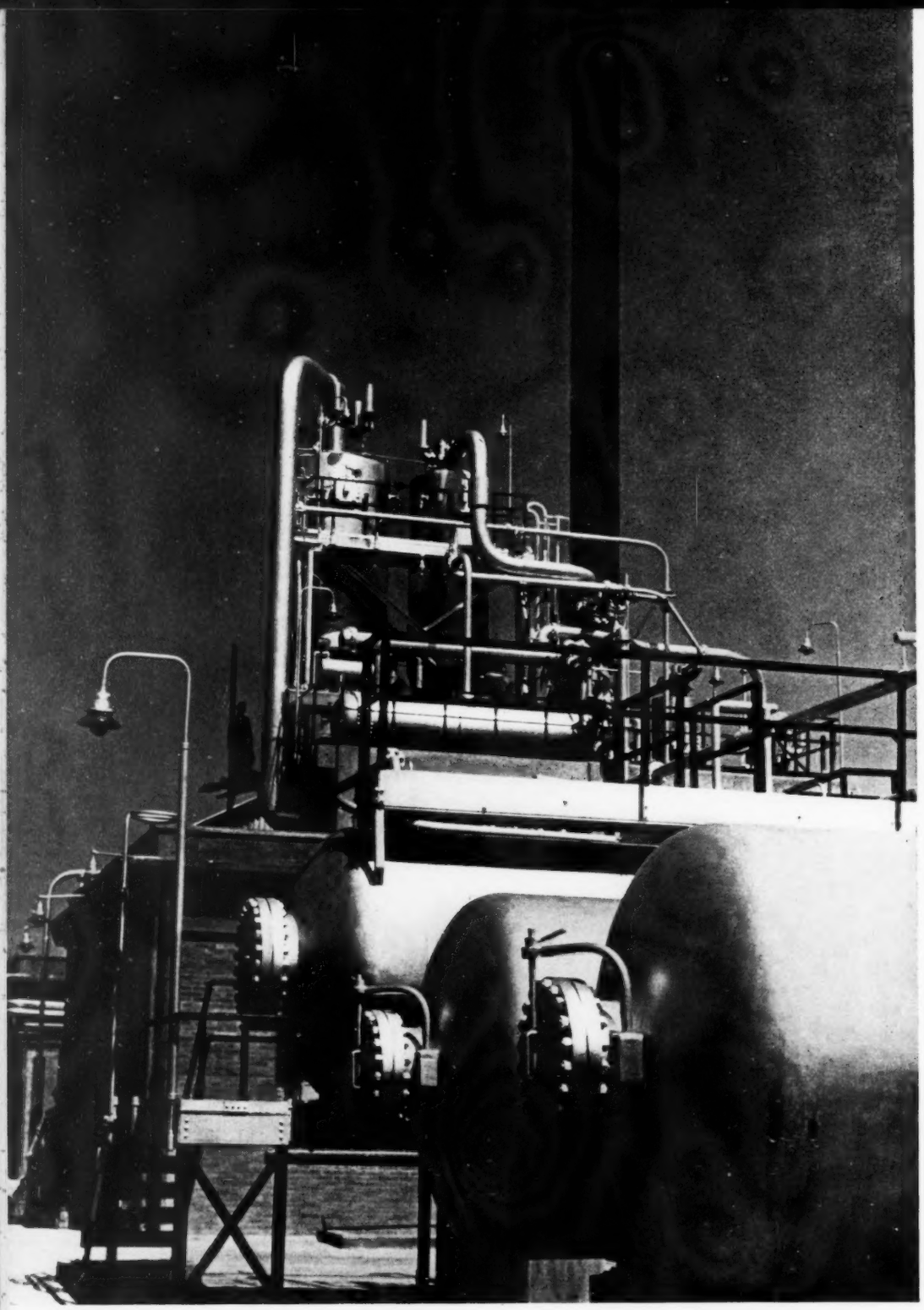
PEOPLE in the petroleum industry are accustomed to say: "Oil is where you find it." But this adage does not cover all cases. It is equally true that where no oil is found it may be made.

The fact is that there are now two grand divisions of the petroleum industry. Of these the principal one is based on the exploitation of ready-made petroleum which nature has more or less effectively concealed in the bowels of the earth. The other is based on the exploitation of materials that become petroliferous only after receiving the attention of chemists and chemical engineers. Nature has thus made it possible for nearly any country on earth, even those without natural petroleum, to obtain and use oil and oil products, provided, that they have access to fossil carbon in one or another of its many forms.

Although nearly any country may thus provide itself with oil, the two methods of obtaining it differ vastly in convenience and cost. To obtain ready-made natural petroleum it is only necessary to find an oil bearing horizon, sink a well therein, and the oil will either come out under pressure supplied by the formation itself, or it may



Cracking unit at one of the world's largest complete refineries, Whiting Indiana.



Modern oil refinery at Naples, part of Italy's national oil refining program which has been making notable progress.

be inexpensively raised by a pump. On the other hand, in a country that is unlucky enough to have no natural oil deposits, it is necessary to mine bituminous coal or lignites by hand labor that is more or less effectively complemented by machinery. These fossil carbons have then to be transported to immense factories where they go through an intricate process in contact with other materials, whereby the entering solid coal comes out as liquid petroleum. The synthetic petroleum answers most of the purposes required of the natural product, but the difference in cost is enormous. Natural petroleum is produced so easily (after you find it) in such large quantities and can be shipped long distances at such a low cost that it falls into that class of commodities described in common parlance as dirt cheap. It is a fact that at the present time, and even under the most favorable conditions, the synthetic product costs three to three and a half times as much as natural oil.

In view of this difference in cost there may be some wonder that any one should embark on the manufacture of petroleum from coal. It is a time-honored principle of classic economics that people will buy in the cheapest markets. But a low price, even a very low one, is not always a sure sign of a cheap market. Though natural oil products from the American Gulf Coast can be laid down in Germany, for instance, at little more than a fourth of the cost of manufacturing the same products from German coal, the fact is that the Germans find an economic as well as a military justification for their synthetic product.

This apparently anomalous situation, which some petroleum economists find difficult to understand, arises from the special nature of foreign trade. Normally commodities that cross national boundaries are paid for by commodities of equal value that cross in the opposite direction. When this exchange of values is unequal, that is, when more value in the form of goods is brought in than moves out, the difference must be compensated by a gold payment. This is the historic method and is a simple matter if the importing country has plenty of gold, but at the present and for any foreseeable time Germany (for example) has practically no gold. Germany trade balances for the most part can now be paid only by the forced exportation of domestically produced goods for what they will bring, regardless of cost of production. Thus it comes about that it actually requires fewer hours of German labor and fewer units of German capital to manufacture a ton of synthetic petroleum than to make enough salable export goods to pay for a ton of the foreign natural product. In that sense the synthetic product is the cheaper.

Therein is found one sufficient reason why Germany (Italy, France, Japan and certain other countries are more or less in the same boat) is devoting a large share of the national wealth to the establishment of a national synthetic petroleum industry, with the avowed intention of displacing completely foreign petroleum from the German market. This transformation was originally to be achieved within the Nazi four-year plan, but the project has advanced so well that the Fuehrer has decreed that it shall be complete within the next eighteen months.

Then there is another reason that lies beyond purely economic considerations. There is still such a thing as war, and in war time international trade is apt to be suspended and the inflow of foreign petroleum shut off. But petroleum is never so badly needed as in war time; an army

without oil cannot even get into action in a modern war. So, as part of its indispensable military establishment, a great power without natural petroleum resources thinks it must create a synthetic petroleum industry at whatever cost.

A few years ago the spread of synthetic petroleum might have been looked upon as a threat to the natural petroleum industry. At the present time, however, it is recognized that demand for petroleum products is growing far more rapidly than new sources of supply are being developed. There is every prospect that this will continue to be the case and that the only effect of substitute fuels will be to relieve to some extent a pressure that otherwise might put an undue strain upon the natural supply. Until synthetic products can be turned out much more cheaply than at present they cannot compete on equal terms in the world market with those derived from natural petroleum.

GERMAN PROBLEM

As regards Germany the arithmetic of the immediate situation is simple. The annual consumption of petroleum products in 1936 amounted to 5,150,000 tons. In the same year the production of the existing German oilfields was about 470,000 tons. The deficit, which has to be made good either by imports or by manufacture of substitutes, or by both, is therefore about 4,680,000 tons. However, this leaves out of consideraton the fact the German oil consumpion is sharply rising. The 1936 consumption of 5,150,000 tons was more than a million tons greater than the 1935 consumption, due to an increase in the number of automotive vehicles and especially to the growing industrial use of the Diesel engine. It may be noted, parenthetically, that this increased consumption appears to indicate that, under German conditions, the cost of fostering a synthetic oil industry may be high but it is not prohibitive.

Deduction made for subsidiary fuel such as alcohol, by-products from the distillation of coal, and for the direct use of coke and charcoal in gasogenes the Germans have to import, or to make, about 4,000,000 tons of oil. It is against this 4,000,000-ton deficit that they are throwing their resources of men and materials with the intention of wiping it out in a comparatively short time.

The first beginnings of the synthetic petroleum industry date back some thirty years, when Sabatier, a Frenchman, discovered that methane, the simplest of the hydrocarbons, could be made from a mixture of carbon monoxide and hydrogen with the aid of a catalyser. This discovery slumbered in the scientific literature for 15 years. In the meantime Bergius, about 1913, invented a process for liquefying coal by heating it under pressure with hydrogen; under these circumstances the carbon of the coal was converted into liquid hydrocarbons, but the yield was small and for the time being nothing came of the Bergius process. Then about 1923 the great German chemical concern I. G. Farbenindustrie (then Badische Anilin-und Soda-Fabrik) took up the Bergius idea. This concern had previously acquired large experience in catalytic chemical reactions involving hydrogen, notably in the ammonia synthesis, and the idea was suggested of adding a catalyst to the Bergius mixture of coal and hydrogen. A large experimental plant was built at Ludwigshaven a/R, and after much trouble a catalyst was found that would have a long life and give worthwhile yields of oil.

What is to become of the existing large Italian oil refining industry which is now working on imported crudes?

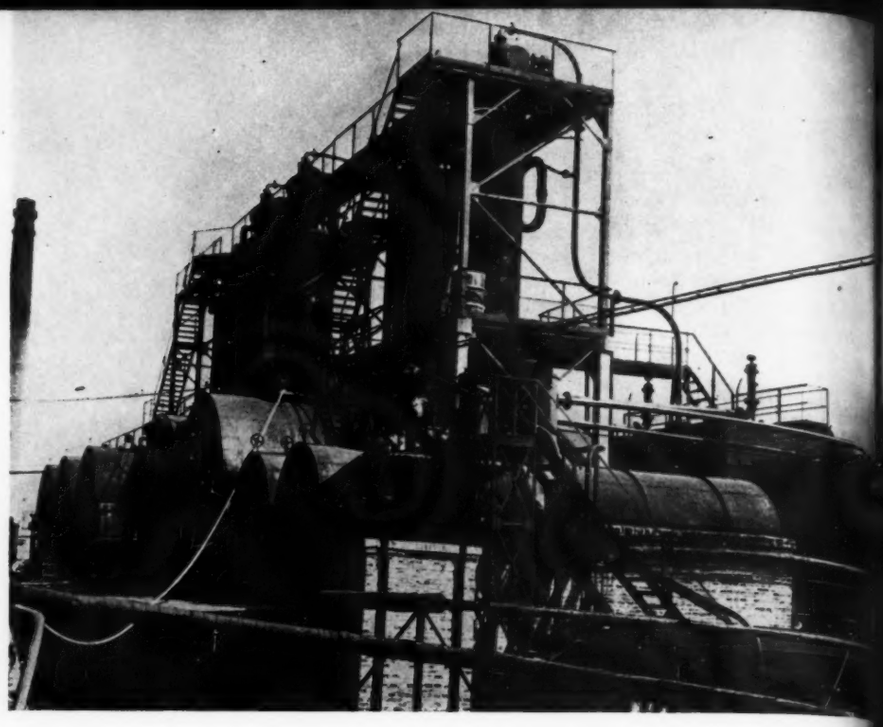
In brief outline the I. G. F. process as it now stands is as follows: the coal, which may be bituminous coal or lignite, is ground in a mill and made into a paste with some heavy oil or coal tar; this gives a mixture that is liquid enough to be pumped. The catalyst is mixed in, hydrogen gas is forced in under pressure, and the mixture is passed into an appropriate furnace where it is heated to a required temperature; hydrogen is absorbed by the coal, and the result is a mixture of liquid and gaseous hydrocarbons very similar to natural crude petroleum. This mixture is passed through columns where the fractions corresponding to gasoline, kerosene, gas oil, lubricating oil, heavy oil, etc., are separated. The heavy oil is separated from the ash constituents and other insoluble matters and reused to make a fresh oil-coal slurry. This once-through process does not give a high yield of gasoline, which is the most desired product, but it is then a simple matter to crack or to hydrogenate the gas oil or middle oil in vapor phase and thus greatly increase the production of gasoline.

This I. G. Farbenindustrie process is now the main reliance for the production of synthetic petroleum in Germany and certain other countries. For controlling the patent rights outside of Germany (except the United States) there has been formed an international company, The International Hydrogenation Patents Co. (I. H. P.). The patent rights in the United States are held by the Standard Oil Co. of New Jersey and the Standard I. G. Co.

Plants Using I.G.F. Process in Germany

Location		Raw Material	Yearly Capacity, tons
Leuna	I. G. F.	Lignite, tars, residues	350,000-400,000
Bohlen (Brabag I)	Braunkohle A. G.	Coal, tar	175,000
Magdeburg (Brabag II)	"	" "	175,000
Scholven	Hibernia Colliery Co.	Bituminous coal	125,000
	Total		825,000

But this is only the start. The Germans appear to have a fixed purpose to enlarge their synthetic oil industry until it can take care of the whole oil requirement of the country, regardless of how consumption may hereafter increase. The very fact that consumption is increasing in the face of the high selling price of gasoline and oil indicates that there is little risk in vigorously pushing the further development of the industry. In addition to the plants that are now working by the I. G. F. process four or five others are being projected. Details of these new plants have not been clearly announced, but it is understood that they will have a combined annual capacity for producing a million tons of synthetic petroleum. The I. G. F. process is therefore in the way of contributing about 1,820,000 tons toward wiping out the German oil deficit.



Above, Jersey Standard's petroleum refinery at Trieste, Italy. Right, absorber and still in gasoline plant at Britten, Oklahoma.

However, the I. G. F. process is not the sole reliance. About the time the I. G. F. was perfecting the Bergius process, a process of a different type was being developed by two Germans, Fischer and Tropsch. This process harks back to the original discovery of Sabatier, who showed that carbon monoxide could be converted into methane by catalytic hydrogenation. In the Fischer-Tropsch process this catalytic reaction is managed so that the formation of hydrocarbon is not limited to methane, but is made to produce a whole series of hydrocarbons, and in fact to give a product closely resembling natural crude petroleum which needs only to be separated into gasoline, gas, oil, and other products.

The first step in the Fischer-Tropsch process is the very familiar one of producing water gas by blowing steam over red hot coke, or briquetted brown coal. The water gas reaction is managed so as to produce a mixture of carbon monoxide and hydrogen in the right proportions, and this gaseous mixture is passed over a suitable catalyist; the resulting liquid products are then separated into the commercial gasoline and oil grades. Plants now operating by this process in Germany are:

RUHRBENZIN A. G. (subsidiary of Ruhrchemie A. G.) at Sterkrade-Holten; this plant works on brown coal briquettes to produce 25,000 tons of oil a year, and is understood to have received orders to increase this capacity to 150,000 tons.

KLOCKNERWERKE-WINTERSHALL A. G. (Mittel Deutsche Treibstoff und Oelwerke A. G.), which operates the Gewerkschaft Viktor, Castrop-Rauxel; capacity 30,000 tons a year.

RHEINPREUSSEN A. G., Homberg, operating on coke; capacity 30,000 tons a year.

The future program for the Fischer-Tropsch process has not been definitely announced, but it is understood that the existing plants are to be enlarged and supplemented by new ones for a combined output of 750,000 tons annually. This production, in conjunction with the output of plants operating by the I. G. F. process, means that German synthetic oil production is or soon will be in the neighborhood of 2,600,000 tons. It will not long rest at that point if the German technologists succeed in carrying out the orders to make Germany's oil autarchy complete in 18 months. It would appear that nothing now stands in the way of this objective. The German consumer is apparently willing and able to pay the price and as General Goering has said, "we have the coal and the know-how". There is enough coal in Germany to last 500 years at the present rate of consumption, and the German technologists have the details at their finger tips.

Raw Materials Required to Make a Kilogram of Gasoline

Process	Raw Material	Quantity in kg.
High pressure hydrogenation (I. G. F.)	Bituminous coal	1.66
	Crude brown coal, dry	2.50
	Brown coal tar	1.25
Synthetic (Fischer-Tropsch)	Brown coal briquettes	10.00
"	Coke	5.4
Cracking	Brown coal tar	2.7

Yields by the I. G. F. process are distinctly better than by the Fischer-Tropsch

but the latter has certain compensating advantages in construction and operation. Also, it fits in well with the important low temperature coal carbonization process used in the manufacture of gas and light distillate (benzol) which is directly usable as motor fuel, but which also produces much coke that would otherwise be a drug on the market.

To repeat, the German synthetic oil industry owes its existence primarily to the country's extremely difficult exchange position. Even the most optimistic German economists admit that Germany's foreign trade will never regain its former importance; German autarchy in oil and certain other essential commodities is therefore inevitable and will be permanent.

ITALIAN AUTARCHY

The petroleum situation in Italy is much the same as that confronting Germany, perhaps even more difficult because of a dearth of coal. There is a nearly complete lack of natural petroleum deposits in the Italian peninsula, the oil deposits in the Italian-controlled kingdom of Albania are relatively small, and if there are any oil resources in Libia or Ethiopia they remain to be discovered. The internal economic situation is practically the same: very small gold reserves and a great and apparently permanent inability to create large trade balances by exports in order to finance imports. Hence the Italians, like the Germans, are driven to base their national economy as widely as possible on an autarchic foundation, and autarchy for their petroleum industry is considered all the more necessary because of the prospects of war and the memory of sanctions applied by unfriendly hands in the Ethiopian affair.

The earnestness with which the Italians are striving for oil autarchy is apparent in the measure now in effect to utilize all possible domestic sources of motor fuel. December 31, 1937 has been fixed as a deadline when all omnibuses and other public means of transportation of passengers on the roads must be equipped with gasogenes which burn charcoal, coke or compressed natural gas derived from national sources. The Corporation of the Sugar Beet has been entrusted with the task of putting enough land in sugar beets to supply enough alcohol to make a 20 percent alcohol-gasoline mixture for all gasoline-driven autos and industrial engines, and a mixture of ethyl alcohol and castor oil is prescribed for Diesel engines to the full extent of available supplies of castor oil.

However, the sum of all these substitute fuels still leaves a wide margin in which the use of petroleum is indispensable. Italian consumption of automotive fuel amounts to about 500,000 tons a year.

Distribution of Italian Consumption

	Gasoline	Heavy Oil	Total
Omnibuses[1]	28,000	2,000	30,000
Trucks	170,000	150,000	320,000
Touring cars	120,000	.....	120,000
Motor cycles, side cars, etc.	30,000	.....	30,000
		Total	500,000

(1) After December 31, 1937 all omnibuses will operate by gasogene.

How these requirements are to be met is given in the following tabulation of the official program laid down for each possible source of supply:

350,000 tons of oil from national sources, to include:

(1) 100,000 tons from the distillation of calcareous asphalts and bituminous schists;
(2) 170,000 tons from treatment of national lignites;
(3) 120,000 tons from the Albanian oil deposits;
(4) 106,000 tons of alcohol from agricultural products;
(5) 12,000 tons of gasoline from the national oil wells;
(6) 12,000 tons of gasoline replaced by natural gas;
(7) 85,000 tons of gasoline replaced by solid fuels;
(8) 6,000 tons of crude benzol from coal distillation.

611,000 tons

It has been decreed that this program shall be fulfilled in 1938. According to a report presented by Signor Di Vimercate to the recent World Petroleum Congress in Paris it will be 80 percent fulfilled by the end of 1937. Items (4) to (8) in the above tabulation are already provided for. Items (2) and (3) are in the way of fulfillment by the new factories at Bari and Livorno, which are ready to apply catalytic hydrogenation to make gasoline and lubricating oils from the asphaltic Albanian crudes. These plants are also in the way of being equipped to hydrogenate lignites in fulfillment of item (2). There remains item (1) which is to be covered by a new factory erected in the

neighborhood of Florence for the distillation of bituminous limestones and schists, and hydrogenation of the products. These oil bearing rocks are found in Sicily, Latium and the Abbruzzias, and together with the lignites of Ribolla and Valdarno are sufficient in volume to form the base for an Italian synthetic oil industry for many years to come.

There immediately arises a question as to what is to become of the existing large Italian oil refining industry, which is working on imported crudes. The expectation is that when the national needs have been satisfied from national sources as per program, these refineries will continue to import crude oil and make finished products for export, or for military purposes.

The three hydrogenation plants here referred to are under control of the Azienda Nazionale Idrogenazione Combustibili (ANIC).

JAPANESE AUTARCHY

The oil situation of Japan is a replica of that of Germany and Italy: absence of nationally controlled petroleum deposits, a decidedly difficult position in international trade, and a pressing necessity for assuring a supply of petroleum products for national defense.

The Japanese oil consumption in 1936 was about 2,750,000 tons, and as in Germany, consumption is increasing. In view of the existing situation the government has called on the Japanese parliament to support a seven-year plan that is well described as gigantic. This plan is based on the assumption that in 1943 the Japanese oil consumpion will amount to about 5,300,000 tons, or practically double what it was in 1936. It is expected that by that time oil sources of one sort or another will be furnishing 1,250,000 tons of light and 1,290,000 tons of heavy oils.

Source of Japanese Supply in 1943

	Motor fuel, tons	Heavy oils, tons
Direct liquefaction of coal	600,000	420,000
Synthetic petroleum	390,000	210,000
Low temperature carbonization	40,000	510,000
Alcohol-gasoline	400,000	
Refined products of national crudes	90,000	150,000

This projected 1943 production will be about 2,500,000 tons short of the consumption estimated for that time. The difference will be made up by treating imported crudes in the national refineries or by direct importation of finished products.

An essential part of this program must be filled by the production of about 1,620,000 tons of synthetic petroleum by some forms of the I. G. F. and Fischer-Tropsch methods. Just what process will be used has not been given out but it is known that Japanese chemists have studied the matter intensively and have developed new and improved catalysts, besides sending engineers to study German methods.

As a starter the parliament voted 10,000,000 yen for building a pilot plant that will produce about 30,000 tons of synthetic gasoline a year. The Mitsubishi concern has under way a project to build a hydrogenation plant to begin operations in 1938 with a yearly capacity of 35,000 tons of finished products; it is understood that in three years the capacity of this plant will be enlarged to 100,000 tons.

But Japanese hopes of partial if not complete oil autarchy are mainly pinned on a collection of plants to be erected by the Manchurian Coal Liquefaction Co., founded by the South Manchukuo Railway with participation by the government and a number of large Japanese industrial concerns. These plants will be located at Fushun, 50 kilometers east of Mukden. Here is now in process of exploitation what is described as the world's greatest open pit coal mine, which in 1936 produced 8,773,000 tons of bituminous coal at a mining cost of less than one yen a ton. The coal seams at this mine have a total thickness of 125 ft. and the coal is of excellent quality for treatment by high pressure catalytic hydrogenation. Plans for hydrogenation operations at Fushun call for an eventual production of 1,500,000 tons of gasoline a year.

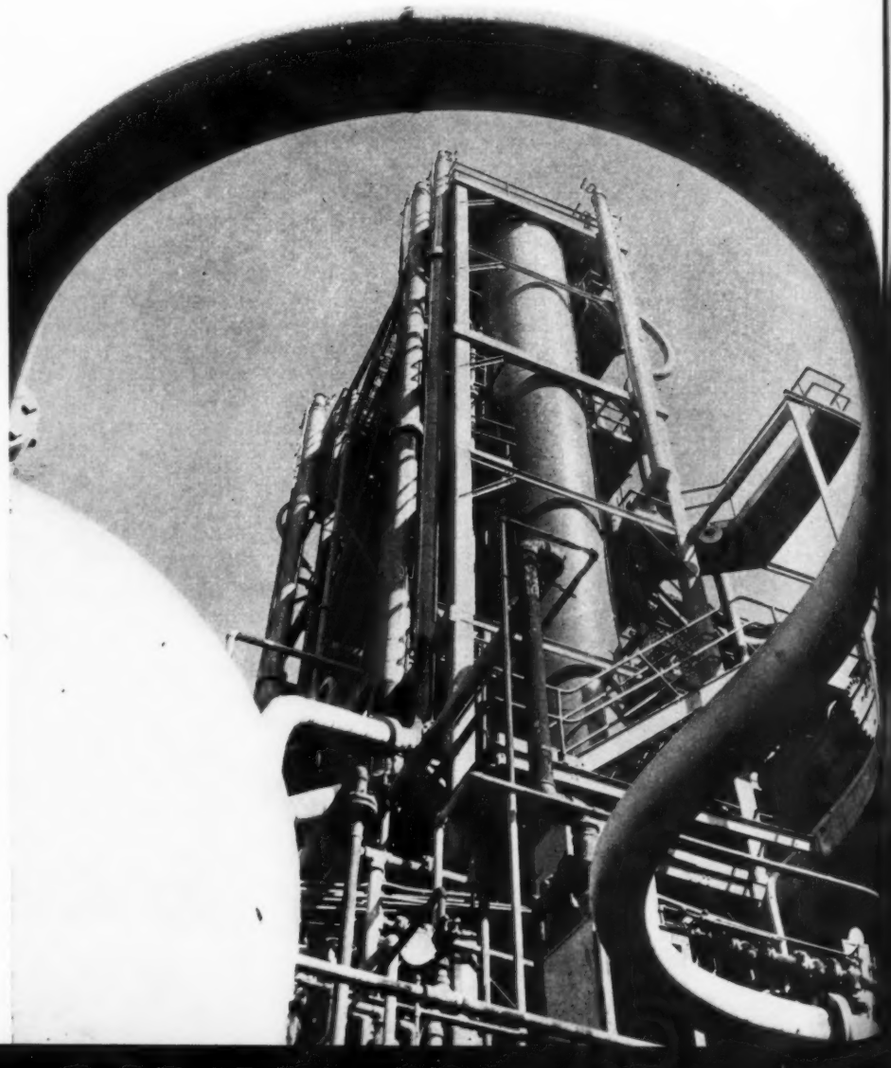
Further, the coal deposits at Fushun are overlain by a deposit of oil shale nearly 500 ft. thick, with an oil content varying between 2 and 10 percent. A plant for distilling this shale is already in operation; during 1936 its production amounted to 104,000 tons of petroleum products.

Coal liquefaction by a form of the I. G. F. or a similar process is to begin at Fushun in 1938 with a plant having an initial capacity of 20,000 tons of finished products a year. Steps are also being taken to produce liquefied coal products from Korean coal. All these various enterprises are more or less affiliated through a national company, the Teikoku Nenryo Kogyo Kaisha which will have a total capitalization of 650,000,000 yen.

In addition, the production of alcohol for motor-fuel purposes is to be stimulated.

OTHER COUNTRIES

Among other great nations with few indigenous oil resources is France. On the surface it would appear that the French, who are fairly well supplied by their own pipeline and tankers for conveying Iraq crude to French refineries, have no need to complain that the subsoil of France contains little petroleum. But the recent shift in the Mediterranean political situation has shown that the supply of Iraq oil is exposed to risk of interruption under certain contingencies. On the other hand,



should the French be cut off from outside supplies of oil they would be faced with the practical impossibility of setting up a national synthetic petroleum industry because the country does not possess coal or lignite deposits to supply even its ordinary needs for industrial fuel, and are obliged to import large quantities of coal from Germany and England.

A really important French synthetic oil industry founded on imported coal is hardly to be thought of, because it is just as easy to import oil as coal and certainly no more risky. Hence France is irrevocably committed to oil importation and to a foreign policy that will under all circumstances permit oil tankers to reach French ports.

For these reasons synthetic petroleum is almost but not quite an academic subject in France. There are at present three small hydrogenation plants in France, one at Bethune, one at Lievin and the third at Courrieres. The latter is the most pretentious of the three, and is being operated by the Societe Produites Chimiques Courrieres-Kuhlmann to produce 25,000 tons of synthetic petroleum products a year. This plant began operation in June 1937 and works by the Fischer-Tropsch process. It receives no government assistance in any form except tariff protection; but even so the operations are profitable, which is an additional demonstration that synthetic petroleum is commercially a paying proposition in a market where the public does not regard the price as prohibitive.

Another great nation without indigenous petroleum deposits is Great Britain. However, the matter of a national synthetic petroleum industry is here not a burning question, although the British, having abundant supplies of coal, could establish and maintain one if they so desired. The position of Britain as a sea power appears at the moment to be paramount and there is little fear that the inflow of cheap imported petroleum will be interrupted. Still, the unexpected may always happen, so partly as a precautionary measure, but more especially to combat unemployment and to help the lagging coal mining industry, the government has indirectly subsidized a coal hydrogenation plant at Billingham. This plant liquefies coal by the I. G. F. process; it has treated 100,000 tons of coal a year, producing 112,000 tons of oil. A plant to operate by the Robinson-Brinley modification of the Fischer-Tropsch process is in the course of development in Scotland.

In addition, the British have a source of motor fuel of some importance in numerous plants engaged in the low temperature carbonization of coal. The light distillates produced in considerable quantities in this operation make an excellent gasoline; the residue of coke provides a superior fuel for household heating that finds a ready market, and there is still talk of generalizing the use of this fuel, which is smokeless, as a means of mitigating the great London fog nuisance. What with this wide market for coke and some government encouragement certain of the British low temperature carbonization enterprises report profits.

WORLD REFINERY Progress Keeps Step with Demand

Growth in Number and Size of Combination Units Feature of Year's Construction Activities — Increasing Attention Directed to Polymerization and Hydrogenation.

TO MEET the constantly growing demand for high test fuels and lubricants the refining industry, during the past year, has expanded its capacity and improved its facilities. The movement toward combination topping and cracking units, which has been in evidence for the past several years, has attained new impetus and recent months have witnessed the completion of a number of plants of capacities that would have been considered astonishing five years ago.

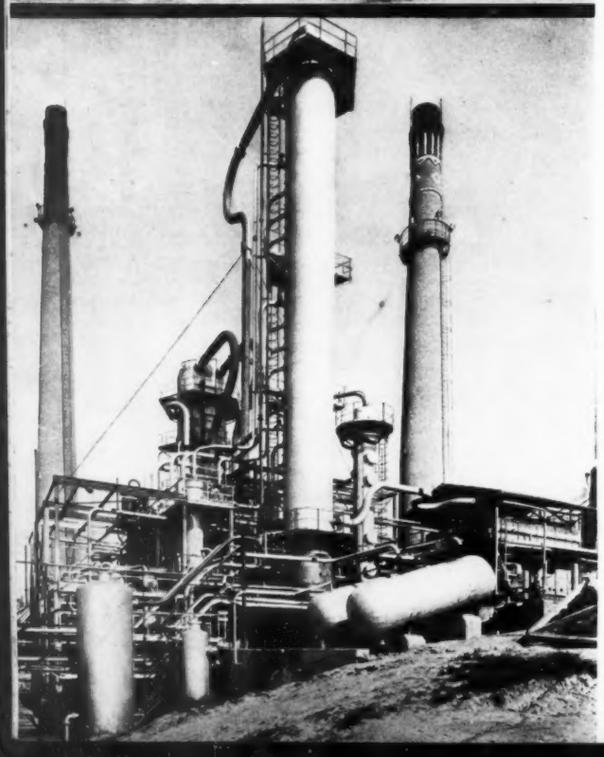
With the role of polymerization in the industry better defined than heretofore the number of plants, both of the thermal and the catalytic type, is steadily increasing. Iso-octane fuels have emerged from the laboratory stage and the commercial demand for gasoline of this type promises to bring about a steady increase in the number of plants supplying it. Hydrogenation has become a subject of live interest for the operating man as well as for those specializing in research and a number of hydrogenation plants are being established. Solvent extraction and dewaxing have reached an established place in the general refinery scheme.

While the small refinery manages to hold its own in supplying local areas there is a steady increase in the average capacity of refining plants and in the number of establishments of extremely large size. There seems to be a well-defined trend also toward the location of refineries nearer to the sources of their crude supply. This is exemplified in the United States by the rapid growth in refining capacity in the Gulf Coast area of Texas. The same tendency is in evidence in other parts of the world, the only exceptions being those countries in which state policy requires that refining for the domestic market be done within national borders.

An illustration of the tendencies above referred to is provided by the complete modernization scheme which the Humble Oil and Refining Company is carrying out at Baytown, Texas. It involves two major construction programs, each consisting of several related projects. The first is a broad, comprehensive set-up for the utilization of excess light ends and the second, an equally large undertaking, is designed for the production of high grade lubricating oils.

One of the major units of the lubricating oil program is a two stage pipe still distillation plant with a designed capacity of 19,000 bbl. daily. This equipment will fractionate paraffinic crudes into ten streams, consisting of light and heavy naphtha, light and heavy refined oil, trade gas oil, cracking stock, paraffin distillate, light and heavy motor oil distillates and fuel oil or residuum. The unit includes three towers designed by Foster Wheeler; a prefractionator, eight feet in diameter and 45 ft. in height, operating at 40 lb. pressure; a huge fractionating tower, 13 ft. by 89 ft., operating at atmospheric pressure, and a wet vacuum fractionating tower 21 ft. in diameter by 76 ft. in height. Separate heating furnaces, designed to operate at coil outlet temperatures of 600 and 800 deg. F., are provided for the atmospheric and vacuum stages respectively.

The second project in the lubricating oil program is a plant, nearing completion, designed to deasphalt, dewax and acid treat residuals and motor oil distillates in propane solution. The plant is designed to take care of 4,200 to 4,850 bbl. daily of



Current refinery construction in pictorial revue, from bottom left to top right: Foster Wheeler installation at the Aquila refinery, Trieste, Italy; new Foster Wheeler unit at the Egyptian government's Suez refinery; Lummus installation at Pure Oil Company's Smith's Bluff, Texas, refinery; and the Toledo, Ohio, Lummus plant belonging to the same concern.

raw residuum through the deasphalting stage; 3,400 bbl. daily of either raw motor oil distillates or deasphalted residuals through the dewaxing stage and 2,400 bbl. daily of dewaxed stocks through the acid treating stage.

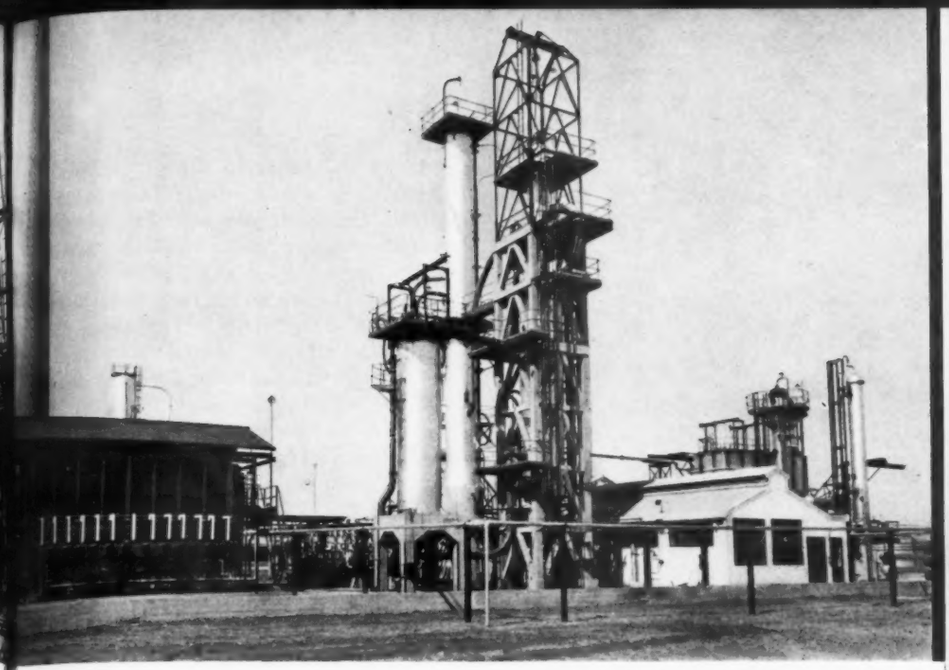
When finally completed, these two units —pipe still and propane plant—will bring about substantially lower refining costs, together with greatly improved quality.

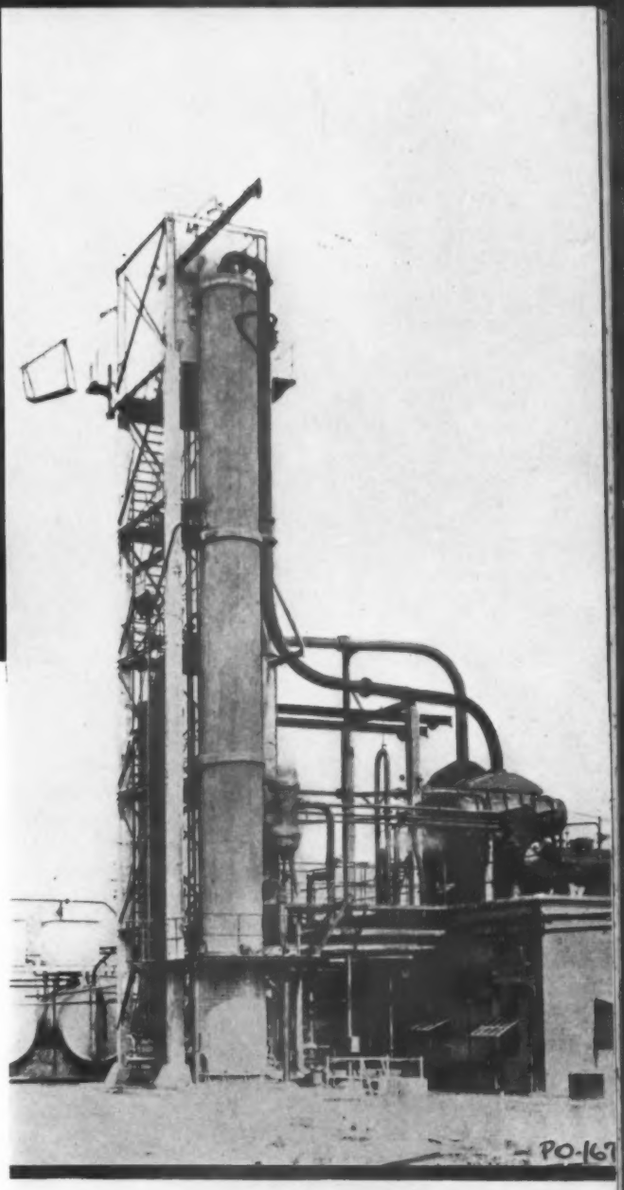
The second major construction program, engineered by M. W. Kellogg Company, also nearing completion, is designed to utilize a much larger portion of excess light ends — butanes and propane — produced both in Baytown refinery and in the great East Texas oilfield. Gathering the refinery gases was a relatively simple matter but the East Texas field offered greater difficulties. It lies some 300 miles to the north of Baytown and in order to bring the butanes and propane to the plant a pipeline had to be provided. This has been done by the Humble Pipe Line Company. The 300 mi. long, 8 in. line came into being largely by converting an existing crude oil pipeline to the butane-propane service. However, despite the fact that much of the line was already in existence a considerable amount of new construction was necessary on the part of the Humble Pipe Line Company in order to bring it over into the light-end transportation service. Installation of three booster pumping stations along the line has made available a daily capacity of 20,000 bbl. Material transported by the line will be a mixture of butanes and propanes in a blend of natural gasoline, having a Reid vapor pressure of approximately 60 lb. Unusual, to say the least, is the fact that no storage facilities are required between East Texas and Baytown; each booster station operates without benefit of either storage or surge tanks. At Baytown, one 5,000 bbl. and two 2,500 bbl. spherical tanks have been provided as surge tanks ahead of the rectification unit. All three of these spheres are built for 100 lb. safe working pressure. The entire stream is metered through displacement meters at both ends of the line, an operation, which has proved accurate within limits of less than half of one percent.

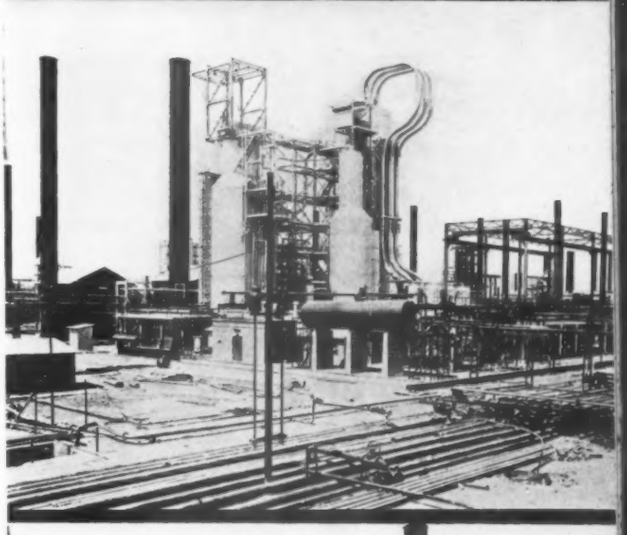
At Baytown, this pipeline stream is rectified in a unit constructed in 1936. Propane is removed in the first column of the unit, which is equipped with 45 plates; a second 40 plate column takes out all the butane fractions and in the third column of 45 plates the overhead butanes from the second column are further separated into iso and normal butane fractions. This unit also contains other columns performing similar operations on light fractions recovered from refinery operations. Stock produced in this equipment will be handled further through the thermal polymerization plant.

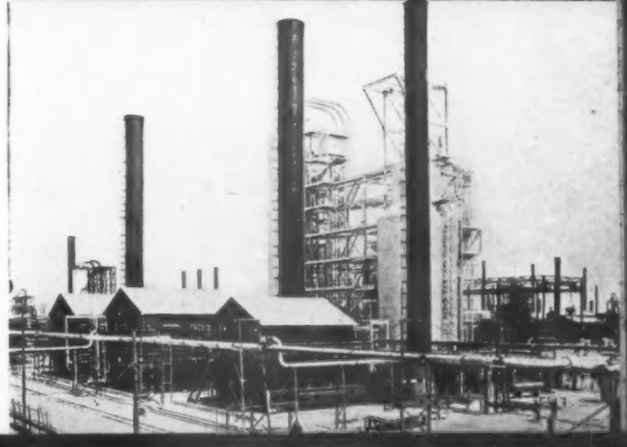
At Texas City, Texas, the Pan American Refining Company is adding a third combination unit of 20,000 bbl. daily capacity to the two similar units already completed. The installation, which will include clay towers, is being made by M. W. Kellogg Company. At Houston, Texas, Shell Petroleum Company is adding to its large plant a 16,000 bbl. Dubbs cracking and reforming unit under the engineering direction of Arthur G. McKee and Company.

Another large combination unit completed during the year is the 22,700 bbl. installation of Atlantic Refining Company









Top left to bottom right: 1,200 bbl. Dubbs single coil cracking unit at the Ancap refinery in Uruguay; Foster Wheeler unit at Digboi, India, belonging to Assam Oil Company, Ltd.; and two pictures illustrative of the large and modern type of equipment now being erected by Anglo-Iranian Oil Company Ltd. at the Abadan refinery—this new unit is a complete topping vacuum distillation plant capable of handling 70,000 bbl. per day.

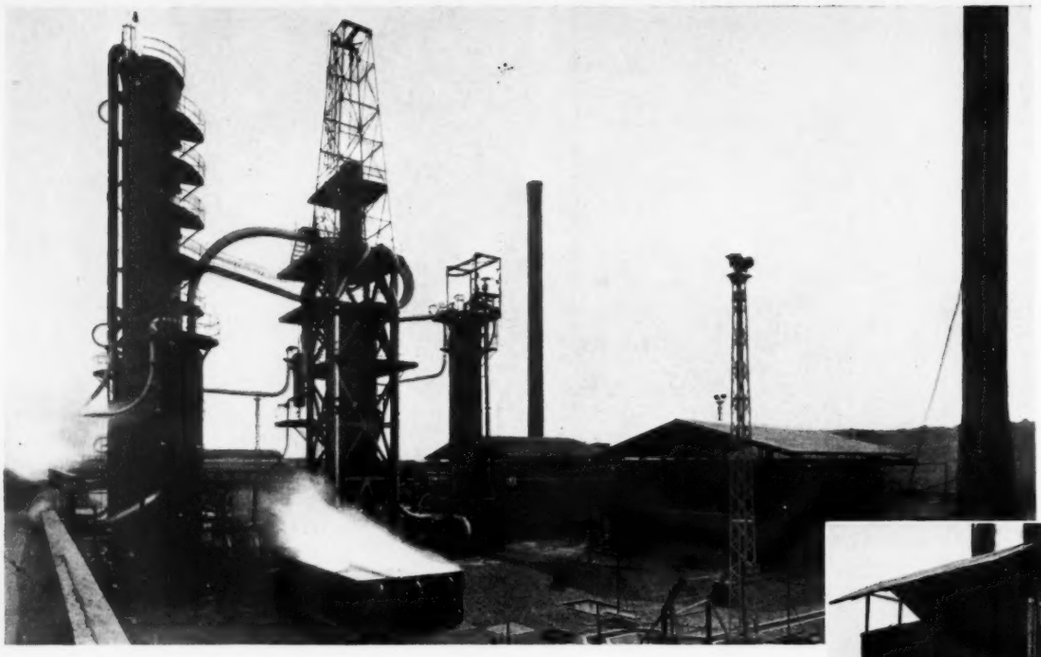
at Atreco, Texas. It includes a cracking unit licensed by Gasoline Products Company, a thermal polymerization unit licensed by Polymerization Process Corporation, two vapor phase treating towers licensed by Gray Processes Corporation, and a hydrogen sulphide removal plant. The plant charges 38 deg. A.P.I. East Texas crude and produces straight run depropanized gasoline, cracked stabilized gasoline, light virgin gas oil and gas. The whole refinery, except tankage, was constructed by M. W. Kellogg Company and includes a boiler house, transformer station, cooling tower, treating plant, office, laboratory, and various auxiliary utility systems.

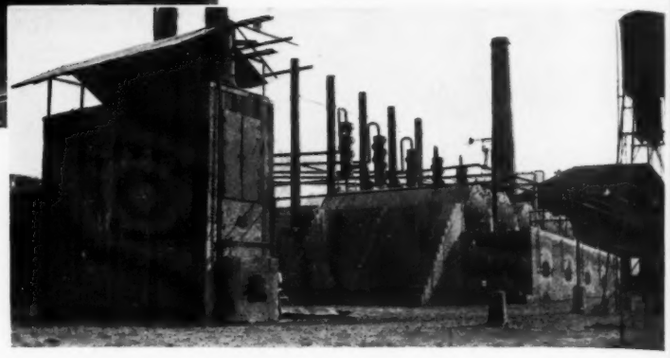
Pure Oil Company has doubled its facilities at Smith's Bluff, near Nederland, Texas, by the construction of a 15,000 bbl. combination high pressure selective cracking unit to operate alternately on Van Zandt, Bosco, East Texas or mixed Gulf crudes. This followed the 10,000 bbl. tube still capable of making solvent naphthas and special naphthas built in the latter part of 1936. Both units have been in operation since early 1937 and were designed and built by Lummus Company. In addition to the above Pure Oil Co. has just placed an order with the Lummus Co. for a 22,000 bbl. combination high pressure selective cracking unit, for their Smith's Bluff plant which is scheduled for completion in the summer of 1938 and is to handle Van Zandt, Bosco, East Texas and mixed Gulf crudes producing a full line of solvent naphthas, gasoline, kerosene, furnace oils and bunker fuel oils. Including the necessary auxiliary equipment such as cooling towers, run down tanks and storage facilities, the investment at Smith's Bluff totals approximately $7,000,000 and will give this refinery a crude capacity of approximately 50,000 bbl. per day.

Other important additions to existing large refineries in Texas include the addition of fufural solvent extraction plants installed by Lummus Company for the Gulf Refining Co. at Port Arthur and for Magnolia Petroleum Company at Beaumont. A hydrogenation plant is being added to the great Port Arthur refinery of the Gulf Oil Corp. At Port Arthur also The Texas Co. is having 16,000 bbl. atmospheric and vacuum crude unit constructed by E. B. Badger Company.

A noteworthy addition to Gulf Coast refining facilities is the new refinery under construction by Barnsdall Refining Company on the ship channel at Corpus Christi. It will consist of a Dubbs cracking plant capable of handling 5,500 bbl. of charging stock per stream day or 5,000 bbl. per cycle day. Placedo crude will be used as charging stock for these stills. Only two products will be turned out, these being 74-77 octane gasoline and a heavy Bunker C fuel oil. The refinery is advantageously located for export and it is stated that a contract has been closed covering the sale to British interests of practically its entire gasoline output for the first year of operation. Wharves and all necessary equipment for loading ships have been installed. In addition to gasoline and Bunker C fuel, provision is made for the handling of crude oil shipments from the terminal located on the refinery site.

Another enterprise located at this rapidly growing Gulf Coast port is the 5,000





Top, Foster Wheeler unit of S. A. de Petroles Jupiter, Rouen; below, new refinery built by Ipiranga S. A., Brazil.

bbl. combination cracking unit of Corpus Christi Refining Company.

At Corpus Christi also is located the 4,000 bbl. plant of the Pontiac Refining Corporation which is now approaching completion. The company is associated with Pontiac Pipe Line Company which is constructing extensive storage at the terminal.

Shamrock Oil and Gas Corporation is erecting a Dubbs cracking plant of 2,750 bbl. daily capacity at Key Station, Texas. Other Dubbs plants constructed in Texas during the year include a cracking unit of 2,750 bbl. daily capacity for McMurry Oil Company at Tyler, one of 500 bbl. for Panhandle Refining Company at Lueders and a 1,600 bbl. cracking and reforming installation for Talco Asphalt and Refining Company at Mt. Pleasant. At Lodi, Texas, Phillips Petroleum Company has constructed a combination natural gasoline and thermal polymerization plant.

Expansion of the Standard Oil Company of Louisiana's large plant at Baton Rouge during the year has included the installation of a propane dewaxing plant built by M. W. Kellogg Company which will use as charging stock 3,500 bbl. daily of phenol treated residuum. Alternatively, it will operate on two distillate stocks. A low pour test dewaxed oil will be produced. A catalytic polymerization unit licensed by Universal Oil Products to process 7,000,000 cu. ft. of refinery gas daily is being built for the company by Arthur G. McKee & Co.

Construction was begun in September at Cotton Valley, Louisiana, of a 3,000 bbl. daily capacity refinery by Octane Oil and Refining Company of Longview, Texas. Another Louisiana undertaking is that of Chalmette Petroleum Corporation for a 9,000 bbl. combination cracking unit licensed by Gasoline Products Company. At Norco, Louisiana, Shell Petroleum Company is installing four large furnaces in conjunction with its natural gasoline plant.

A 2,500 bbl. Dubbs cracking unit has been installed at Cleveland, Oklahoma, by Johnson Oil Refining Company. At Barnsdall, Oklahoma, the Barnsdall Refining Company has revamped its 2,000 bbl. Cross unit and installed vapor phase treating towers. In the Fitts field Magnolia Petroleum Company has established a natural gasoline plant. Empire Refining is having Badger install revisions and additions to 2,500 bbl. solution rerun unit for additional tube operations.

In New Mexico Continental Oil Company has erected a 750 bbl. cracking plant at Artesia and Valley Refining Company a 300 bbl. cracker at Roswell.

National Refining Company has enlarged its plant at Coffeyville, Kansas, by adding a 3,200 bbl. Dubbs cracking unit and Bay Petroleum Company has installed a 2,000 bbl. Dubbs cracking unit at McPherson, Kansas. The latter company also has added a 900 bbl. Dubbs cracking unit to its plant at Denver, Colorado.

Continuing its program of yearly enlargements, Big West Oil Company at Kevin, Montana, has installed a Dubbs cracking and reforming unit of 400 bbl. daily capacity. Independent Refining Company has erected a Dubbs cracking and reforming unit of 1,500 bbl. daily capacity. Other Dubbs installations in this territory include a cracking unit of 875 bbl. daily capacity for Northwest Refining Company at Cut Bank, Montana, and a reforming unit of 675 bbl. capacity for Arro Oil and Refining Company at Lewistown, Montana.

On the Pacific Coast an outstanding development of the year was the recent announcement by Richfield Oil Company of its intention to erect a new $5,000,000 refinery on the site of its present plant at Watson, California, thereby adding approximately 25 percent to its refining capacity. The construction will be in charge of C. F. Braun and Company of Alhambra, California. The new plant will include two modern combination topping and cracking units, each with a daily capacity of 30,000 bbl. and, in addition a catalytic polymerization plant with a daily capacity of 6,000,000 cu. ft. of gas. The refinery will not be completed until late in 1938 and a full description of it will be published later.

Standard Oil Company of California is carrying forward its plans for increased production of high test fuels at its Richmond refinery by installing the first hydrogenation plant on the Pacific Coast. The plant is of the high pressure type and will have a capacity of 1,000 bbl. daily. In addition to the hydrogenation unit, a rerun still for removing heavy polymers from the feed stock and a stabilizer for the final product will be included. The company recently completed a polymerization plant at Richmond with a capacity of 700 bbl. per day.

California Standard is having E. B. Badger and Sons construct a 1,400 bbl. acetone benzol dewaxing unit at Richmond, Calif.

General Petroleum Corp. of California, a subsidiary of Socony Vacuum, has just placed an order for a 14,000 bbl. daily capacity viscosity breaker to charge California reduced crude and to produce low pour gas oil and bunker fuels. This plant will be erected in the Torrance refinery, Los Angeles, and will involve an investment of approximately $1,500,000.00. It is expected to be completed early in the spring of 1938 and will be designed and built by Lummus.

Union Oil Company is installing at its Oleum, California, refinery a cracking plant

with much auxiliary equipment. The Associated division of Tide Water Associated Oil Company is carrying out a $2,000,000 program of improvement at its Avon, California, plant. Included in this are new cracking units and a polymerization plant, both being constructed by Alco Products, Inc.

The cracking units include a modern three-coil cracking plant for optimum production of both volatile anti-knock gasoline and high grade fuel oil. The plant is unique in that provision has been made for breaking up a daily charge of 14,500 bbl. of oil into several fractions so that the bulk of fuel oil is produced under conditions known to yield a product of excellent stability and heating value, while the cracked gasoline is manufactured under conditions favorable to a large yield of motor fuel of high octane rating.

An outstanding feature of the polymerization plant will be the production of a premium grade gasoline of exceptional volatility from more than 5,000,000 cu. ft. of refinery gas per day.

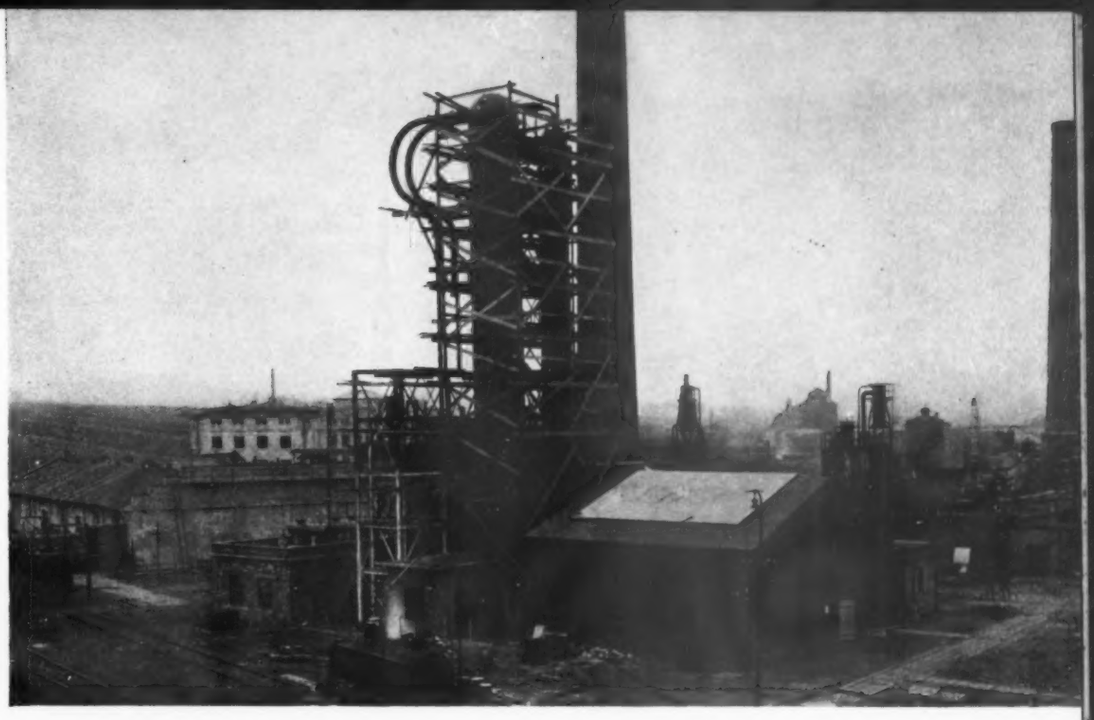
Wilshire Oil Company is constructing a catalytic polymerization unit for utilization of refinery gases at its Norwalk, California, plant. The unit, licensed by Universal Oil Products, has a capacity of 2,500,000 cu. ft. of gas per day with a yield of 5.8 gal. of high octane gasoline per thousand feet.

Ajax Oil and Refining Company has installed a 700 bbl. Dubbs cracking unit at Clearwater, California.

A 3,500 bbl. special design vacuum type tube rerun unit is being installed at Martinez for Shell by the Badger Co.

Coincidently with its expansion program at Smith's Bluff, Texas, and Cabin Creek, West Virginia, Pure Oil Company has been engaged in enlarging its refinery at Toledo, Ohio and the Heath plant near Newark, Ohio. Late in 1936 a combination high pressure selective cracking unit of 8,000 bbl. daily capacity was completed at the Toledo plant by Lummus Company for making high octane gasoline from Michigan crudes and early this year an order was placed with the same company for a duplicate unit which was put in operation in October. Both of these units will produce gasoline, kerosene, furnace oil and bunker fuel oil from Michigan crude. With new additions to the Toledo plant, the daily thruput has been increased by 16,000 bbl. daily, of Michigan crudes which have a lower octane rating than Texas crudes and require a greater degree of refining to manufacture similar products. The two units represent an investment of $4,000,000 including necessary auxiliary equipment such as cooling towers and tanks.

The Pure Oil Company installation at their Heath, Ohio refinery is for a 7,000 bbl. per day high pressure cracking unit to handle Illinois or Mid-Continent crudes producing gasoline and bunker fuels. This unit was also designed and built by The Lummus Company and started operating in the latter part of October of this year. This unit represents an investment of approximately $1,000,000.



Foster Wheeler installation in Poland of Galicja, S. A. Droholycz.

For Standard Oil Company of Ohio, M. W. Kellogg Company recently completed at Toledo a combination topping and cracking unit with stabilizer, handling 14,600 bbl. per stream day of Mid-Continent or Crystal crudes. The products are gasoline of varying octanes and distillation ranges, kerosene, virgin fuel oil, paraffin distillate and fuel oil.

Standard Oil of Indiana is adding to its huge refinery at Whiting, Indiana, a combination cracking unit which will handle 22,000 bbl. daily of Mid-Continent crude to produce high octane gasoline, fuel oil, and coke, or alternatively to produce other specification distillate stocks.

Sinclair Refining Company has made extensive additions to its East Chicago, Indiana, refinery and at Lockport, Illinois, The Texas Company has installed a Dubbs catalytic gas process with a capacity of 3,500,000 cu. ft. of gas per day. Dubbs cracking and reforming units have been installed by Leonard Refineries at St. Louis, Michigan, and by McClanahan Refineries Inc. at the same place. The National Refining Company has installed a Dubbs cracking unit of 3,500 bbl. daily capacity at Findlay, Ohio.

Socony-Vacuum is adding to its Buffalo facilities, an 8,500 bbl. topping and vacuum unit to operate on mixed excise crudes and a 2,000 bbl. pressed distillate rerun unit, both designed by Badger.

Modernization of the plant at Bradford Oil Refining Company at Bradford, Pennsylvania, now under way, involves changes amounting to complete reconstruction. It includes a cracking and reforming unit of a daily capacity of 1,000 bbl. under license from Petroleum Conversion Corporation.

Another unit of the refinery is a 600 bbl. methyl-ethyl-ketone dewaxing plant licensed by Texaco Development Co. and installed by Lummus Company to produce low cold test neutrals and bright stocks. All grades of lubricating oils will be finished, partly by contacting and partly by percolation.

E. B. Badger have designed and installed a 1,500 bbl. acetone benzol dewaxing unit for Quaker State at Bradford.

Kendall Refining Company of Bradford has added to its facilities a deasphalting and dewaxing plant installed by M. W. Kellogg Company. This unit charges 1,100 bbl. per day of cylinder stock from Bradford crude or alternatively 1,160 bbl. per day of distillate stock from the same crude. It produces a zero pour dewaxed oil. The plant is licensed under patents of the JUIK group, controlled jointly by Standard Development Company, Union Oil Company, and Standard of Indiana.

A noteworthy addition to Atlantic Coast refining facilities during the year is the thermal polymerization plant built by M. W. Kellogg Company for Atlantic Refining Company at Philadelphia. This is a complete polymerization and feed recovery plant which handles the gases of the refinery, producing approximately 1,750 bbl. per stream day of polymerized gasoline of high octane number. The plant is licensed by Polymerization Process Corporation and represents an investment of $2,100,000. At

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General view of the Y.P.F. refinery at La Plata; on the right, a new suburb of comfortable villages for employees and workmen.

Point Breeze also, the Atlantic Refining Company has installed a hydrogen sulphide removal plant utilizing the Koppers process.

Gulf Refining Company has just placed in operation at Neville Island, Pennsylvania, a Foster Wheeler two stage atmospheric and high vacuum crude oil distillation unit of 3,300 bbl. daily capacity. It is designed for the production of light gasoline, light, medium, and heavy naphthas, kerosene, gas distillate and cylinder stock.

At Marcus Hook, Pennsylvania, Sinclair Refining Company has installed two catalytic polymerization furnaces to process 4,250,000 cu. ft. of gas daily. Also at Marcus Hook Congoleum-Nairn Company has erected an 8,100 bbl. asphalt furnace and Badger has constructed a 2,800 bbl. asphalt unit for The Texas Co. Koppers Company has installed an oil furnace in its plant at Pittsburgh. Elk Refining Company at Warren, Pennsylvania, has doubled the capacity of its Dubbs cracking unit to 800 bbl. daily.

For Pure Oil Company, during the first half of the year, Alco Products completed and put on stream at Cabin Creek, West Virginia, a $1,000,000 unit, handling 3,500 bbl. daily of Pennsylvania crude. The output includes a full line of lubricating oils, gasoline, kerosene, and bright stock. The same unit handles a similar volume of Mid-Continent crudes producing gasoline, kerosene, and fuel oil. At Falling Rock, West Virginia, Elk Refining Company has installed a Dubbs cracking unit of 800 bbl. daily capacity.

In spite of the labor troubles that have beset the oil industry of Mexico, numerous important additions have been made to Mexican refining facilities during the year. Mexican Eagle (El Aguila) has installed at Tampico a Gyro cracking unit of 6,000 bbl. daily from Pure Oil Company design and is preparing to add several other units. These will include a 30,000 bbl. atmospheric topping unit, a Dubbs reforming unit of 11,000 bbl. daily capacity and a catalytic polymerization unit designed by Universal Oil Products Company to process 5,000,000 cu. ft. of refinery gas daily. With these additions the daily charging capacity of the refinery will be raised to 56,000 bbl. daily.

Anglo-Mexican Petroleum Company at Tampico has installed a Foster-Wheeler crude oil distillation furnace of 15,000 bbl. daily capacity and the Pierce Oil Company has added a similar furnace of 6,000 bbl. capacity to its Tampico plant. Petromex, the government-backed company, has installed a 2,000 bbl. Dubbs cracking unit in its refinery at Tampico.

N. V. de Bataafsche Petroleum Maatschappij at Curacao has installed a 28,000 two-stage topping unit, designed by Badger to operate in conjunction with an existing vacuum unit.

Existence of a high import duty on petroleum products and a nominal tariff on crude has led to the establishment of a number of refining plants in Brazil during the past two years. Several of these are simple distillation plants producing gasoline from fuel oil, but the movement toward the erection of complete refineries is now assuming greater proportions. During 1936 a plant was erected at Uruguayanna in the extreme southern portion of the country with a daily capacity of 200 bbl. while Industrias Reunidas F. Matarazzo S. A. has established a small plant at Sao Paulo. This year another important addition to Brazilian refining facilities has been made by Ipiranga S. A., Companhia Brasileira de Petroleos (Brazilian Petroleum Company) which has erected a plant at Rio Grande, State of Rio Grande do Sul. The plant has an initial capacity of 1,000 bbl. daily and is located conveniently to the port with which it is connected by three pipelines for receiving crude and shipping products. Besides gasoline the refinery produces kerosene, lubricating oils, greases, and solvents from Peruvian and Ecuadorian crudes.

The international companies selling products in the Brazilian market have withheld plans for refinery construction in view of a possible alteration in tariff regulations. If the present tariff policy is maintained, however, they undoubtedly will find it necessary to construct plants within the country, and it is reported that Jersey Standard interests already have plans for a Brazilian refinery under consideration.

Although the ANCAP refinery at Montevideo, Uruguay, was completed only last year, it has been found necessary, in order to meet the increased demand for its products, to add a new light oil cracking furnace and heat exchange equipment to its Dubbs cracking unit which is combined with stabilization and clay treating units and a gas absorption plant. This installation is being made by Foster Wheeler, designers of the original plant.

In Argentina the YPF (Argentine Government Oilfields) is adding a cracking and polymerization unit, built by Alco Products, to its La Plata refinery. From the engineering viewpoint, the significance of this arrangement is the combination of the cracking plant and the polymerization unit which effects major economics in design and operation by utilizing a common fractionating system, gas recovery system and treating plant.

Following the lead of various other countries Venezuela has coupled the granting of drilling concessions in the past two years with a provision requiring the construction of refineries within the country. As a result of such stipulations, Standard of New Jersey, Socony-Vacuum, and Shell all are committed to the erection of refineries in Venezuela. In the case of Shell, this will involve doubling the capacity of its existing plant to 28,000 bbl. daily by adding a new distillation and auxiliary equipment, while the others will build entirely new plants in the eastern part of the country.

Lago Oil & Transport Company is preparing to add a 9,000 bbl. gas oil cracking unit of M. W. Kellogg construction to its refinery at Aruba, D. W. I.

Keeping step with the demand for high test fuels, Trinidad Leaseholds, Ltd., has obtained a license from Universal Oil

Products Company for an iso-octane plant of 1,750 bbl. daily capacity at Trinidad, B. W. I. The plant is being built by Foster Wheeler and is designed for the polymerization and hydrogenation of butane-butylene. It is expected that it will be placed in operation during the coming year. Another addition to be made to the Trinidad Leaseholds plant is a specially designed Foster Wheeler furnace to be used in connection with the gasoline plant.

Some noteworthy additions have been made to the refining facilities of the United Kingdom during the year, particularly for the production of lubricating and fuel oils for which the demand is increasing steadily. The extensive program of additions carried out by Anglo-Iranian Oil Company at Llandarcy, Wales, is the subject of a separate article in this issue.

Construction is well advanced on the new plant of Manchester Oil Refinery, Ltd., at Trafford Park, Manchester. This plant, designed by Moore & George, Ltd., will produce lubricating oils, gas, and fuel oils. It will include a 2,000 bbl. per day vacuum distillation unit and Edeleanu solvent refining and dewaxing equipment. Its output of lubricating oils will be between 20,000 and 25,000 tons yearly.

The Ellesmere Port refinery of Lobitos Oilfields, Ltd., is being extended and altered in order to produce a wider range of lubricating oils than at present, and it is anticipated that the new units will be in operation by the end of the year. A new flash unit has been added to the Weaste refinery of Berry Wiggins & Company, Ltd., and other improvements have been installed in the Kingsnorth-on-Medway refinery of the same company. A detailed account of the solvent extraction plant at Shell Haven appears in another part of this issue.

A project that has attracted a great amount of attention since it involves a monopoly of refining in the Irish Free State is that of the Irish National Refineries, Ltd., The plant, designed by Foster Wheeler, will be located at Dublin and will have a capacity of 10,000 bbl. daily. Since it is intended to supply the demands of the Irish Free State market for a wide variety of products, it is planned to incorporate a high degree of flexibility and to process a variety of different types and grades of crude. Its equipment will provide for prestabilization, atmospheric and high vacuum distillation, cracking and reforming, solvent refining of lubricating oils, wax and asphalt manufacturing and gas processing. Besides its output of light and heavy gasoline, naphtha, kerosene, gas oil, diesel oil, lubricating oil, fuel oil, wax and asphalt, the plant will produce other special products to meet market requirements. Construction work was delayed in its early stages by labor troubles but it is expected that the refinery will be completed and put into operation sometime during 1938.

Air view of one of the world's largest complete refineries—Standard Oil Company of Indiana's Whiting, Indiana, plant.

Having carried through, within the past few years, a program of refinery construction more than sufficient to meet the needs of the domestic market, France has had little reason for embarking on new construction during the current year, but numerous additions to existing plants have been made. At the Martigues refinery of Compagnie Francaise de Raffinage a combination unit of 12,000 bbl. daily capacity is being built by M. W. Kellogg Company for handling Iraq crude. The plant will include cracking, reforming and stabilizing units and will produce gasoline, kerosene, gas oil, and fuel oil. A 15,000 bbl. Kellogg pipe still is being installed at the Gonfreville refinery of the same company. At Bec d'Ambes a thermal reforming unit and a reformed naphtha stabilizing unit are being installed by Societe des Raffineries de Petrole de la Gironde. A Dubbs cracking unit of 500 bbl. capacity has been installed by Societe Lyonnaise at Autun, France. Soc de Raffinage des Huiles de Petrole is adding to its plant at Courchelettes a pipe still of 6,000 bbl. daily capacity installed by M. W. Kellogg Co.

Striking out boldly on its four year program for national self sufficiency, Germany has been actively engaged during the year in constructing plants for the production of oil from coal and lignite. These are described in a separate article. One new refinery that holds a place of importance is the plant of Mineraloel Baugesellschaft at Nordstern, Germany, which has been designed by Foster Wheeler to incorporate several processing units to be operated in conjunction with hydrogenation.

The installation will include two atmospheric distillation units handling 5,000 bbl. daily of hydrogenated products which will be fractionated for the production of gasoline and other products and two additional atmospheric distillation units of approximately 6,000 bbl. daily which will process the hydrogenated product for the production of light and heavy gasoline and medium and heavy oil. The installation includes also a stabilizer and associated equipment to stabilize 5,000 bbl. per day of gasoline to the required vapor pressure. It is expected that the refinery will be placed in operation during 1938.

"Nerag" the Gewerkschaft Neur Erdol-Raffinerie at Misburg near Hanover, Germany has recently put into operation a complete high V.I. lubricating oil refinery designed to produce 900 bbl. per day of finished lubricating oil from native reduced crude.

The refinery which was designed by the Lummus Company and erected under their supervision includes a two stage vacuum unit which incorporates their Coubrough Process, a furfural extraction plant, a contact filtration unit, a ketone-benzol dewaxing plant, a complete barrelling and shipping plant, water system and boiler plant of capacity to produce 75 tons of steam per hour.

At Hollen, Germany, Dr. C. Otto and Company, have installed a Dubbs cracking unit of 825 bbl. daily capacity.

Falling off of production in Poland has tended to restrict refinery expansion but Polmin State Refinery at Drohobycz is installing a Foster Wheeler two-stage atmospheric and high vacuum distillation unit for processing crude oil. It will treat 2,500 bbl. per day, producing light and heavy gaso-

lines, kerosenes, gas oils, wax distillate, cylinder stock, and asphalt residue. The plant is expected to be completed and put in operation during the coming year.

A new refinery has been under construction in Dubova, province of Slovakia, which is owned by the Czechoslovak government and is to process crudes from state-owned wells at Gbely, Slovakia. Its construction is to be completed some time in 1938. The most important innovation during the past past year was the construction of the first cracking equipment in Czechoslovakia by the Apollo Mineraloelreffinerie A. G., of Bratislava. This equipment was manufactured under American patents by Skoda Works, of Prague. The company also installed a new pipe still at its Bratislava plant.

In Austria, Nova A. G. has been engaged in constructing a new refinery at Schwechat to replace its old plant at Drösing. In Hungary, the Iron and Steel Company of Selgotarjan has projected a new refinery at that place. In Bulgaria Petrol Company Ltd., representing foreign oil interests, has established a small refinery at Roustahouk capable of handling about 24,000 tons yearly.

Refinery construction activity in Roumania during the year has related principally to the addition of new units and facilities to existing plants. Particular interest has been displayed in polymerization and production of iso-octanes. Creditul Minier is proposing to establish in its refinery at Ploesti an iso-octane unit, using the Universal Oil Products process, and also a natural gasoline stabilizing unit. Petrol Block likewise is installing at Ploesti a catalytic polymerization and iso-octane plant. Redeventa S.A. has projected a polymerization plant of 1,200 bbl. daily capacity for propane and butane, using either the thermal or catalytic process. Its subsidiary, Xenia is adding an atmospheric distillation unit of Bohrmann type with a daily capacity of 6,000 bbl. Steaua Romana is preparing to install a Dubbs combination topping and cracking unit and Romano-Americana is adding a 2,000 bbl. reforming unit to its Ploesti-Teleajen plant.

Refinery facilities and progress in the Soviet Union form the subject of a separate article. Particular attention has been directed by the Russians to increasing their supply of high test aviation fuels which they have been importing on an extensive scale. With this purpose in view they have obtained licenses from Universal Oil Products Company for four catalytic polymerization plants with a combined capacity of approximately 10,000 bbl. daily. Two of these are located at Ufa, one at Grozny and one at Saratov.

The Lummus Company is at present engaged in building the largest cracking unit the Soviets have yet attempted. This is a 22,000 bbl. daily capacity combination high pressure selective cracking unit designed to handle a corrosive crude. This unit is being erected in the UFA refinery and will produce gasoline, kerosene, furnace oil and bunker fuels.

Nowhere else in Europe has there been greater activity during the year in expansion of refining facilities than in Italy, both through the elaboration of plants operated by the international companies marketing products there and through the projection of plants intended to work on indigenous materials.

Of the latter the most ambitious single undertaking is that of Azienda Nazionale Idrogenazione Combustibili (ANIC) at Bari which is intended to process crudes from Albania in conjunction with a hydrogenation plant recovering oil from native shale and lignite. The refinery, which is being designed by Foster Wheeler, will handle 7,000 bbl. of crude daily.

At Livorno, Italy, Foster Wheeler is constructing for ANIC a complete gas handling plant to process 8,000 bbl. daily of hydrogenated and cracked gasoline, stabilizing it to the required vapor pressure and also stabilizing light gasoline.

Early this summer at Naples, Italy, the Lummus Co. completed a ketone benzol dewaxing plant to operate on a variety of charging stocks for Raffineria di Napoli and Badger constructed a 4,500 bbl. two-stage atmospheric and vacuum unit.

Another interesting undertaking under Italian auspices is that of Raffineria di Olii Minerali per l'Africa del Nord, Anonymia (ROMANA) at Tripoli, Africa. The plant will cover an area of more than 400,000 sq. meters and will handle 100,000 tons of crude annually which may later be increased to 150,000 tons. A series of five pipelines, 2,500 meters long, will connect the refinery with the shipping docks for receipt of crude and shipment of products. While the plant is intended to supply local territory, it has a strategic value also as is indicated by the establishment of a large bunkering station in connection with it.

Civil war in Spain has not interrupted progress on the refinery which Bethlehem Steel Corporation is constructing for Compania Espanola de Petroles S. A. (CEPSA) in the Canary Islands. This is a complete refinery which will include a Dubbs cracking unit of 4,100 bbl. daily capacity, a 3,000 bbl. cracked distillate rerun unit and a treating and doctor sweetening plant of the same capacity, the last two units designed and erected by E. B. Badger and Sons.

Extensive additions are being made to the refinery of Anglo-Egyptian Oilfields, Ltd., at Suez, including completion of a new high-vacuum asphalt plant, installation of a Dubbs cracking unit of 2,300 bbl. daily capacity, additional boilers, a salt water cooling plant and tankage and other equipment.

In the Near East the most significant event of the year has been the completion of the refinery of Bahrein Petroleum Co., Ltd., on Bahrein Island in the Persian Gulf. This plant, which will be formally opened early in December, originally was designed for a daily capacity of 12,500 bbl. daily but this was doubled before construction had advanced very far and the plant as completed will process 25,000 bbl. of crude per day. Its equipment includes a crude still, two Dubbs cracking and reforming units, an acid treating plant for cracked gasoline, a clay vapor phase treating plant, an acid manufacturing plant, lead sulfide treating plant, power plant, steel tankage of 2,000,000 bbl. capacity, marine loading and pipeline facilities. The plant was fully described in October WORLD PETROLEUM.

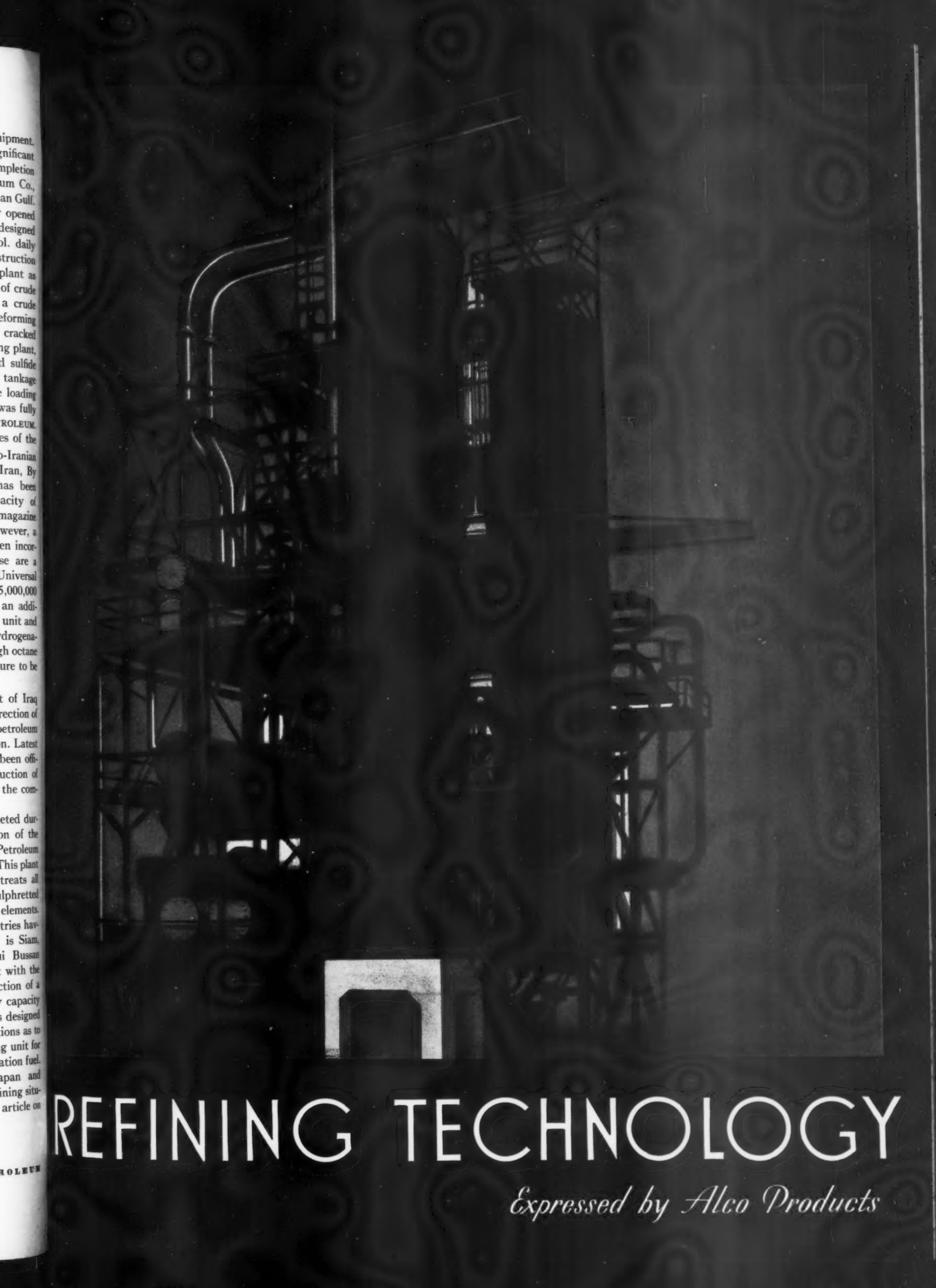
Outstanding among the refineries of the world is the great plant of Anglo-Iranian Oil Company, Ltd., at Abadan, Iran, By successive additions this plant has been enlarged to a daily crude capacity of 260,000 bbl. as described in this magazine a year ago. Since that time, however, a number of new additions have been incorporated or planned. Among these are a catalytic polymerization plant of Universal Oil Products design treating 15,000,000 cu. ft. of refinery gases per day, an additional crude topping and reducing unit and additional cracking capacity. A hydrogenation plant for the production of high octane aviation gasoline is the latest feature to be decided upon.

For some time the government of Iraq has had under consideration the erection of a refinery near Kirkuk to supply petroleum products for domestic consumption. Latest reports are that this project has been officially approved and that construction of the plant will go forward during the coming year.

An important enterprise completed during the year was the construction of the stabilization plant of the Iraq Petroleum Company, Ltd., at Kirkuk, Iraq. This plant built by Foster Wheeler, Ltd., treats all Iraq crude for the removal of sulphretted hydrogen and other undesirable elements.

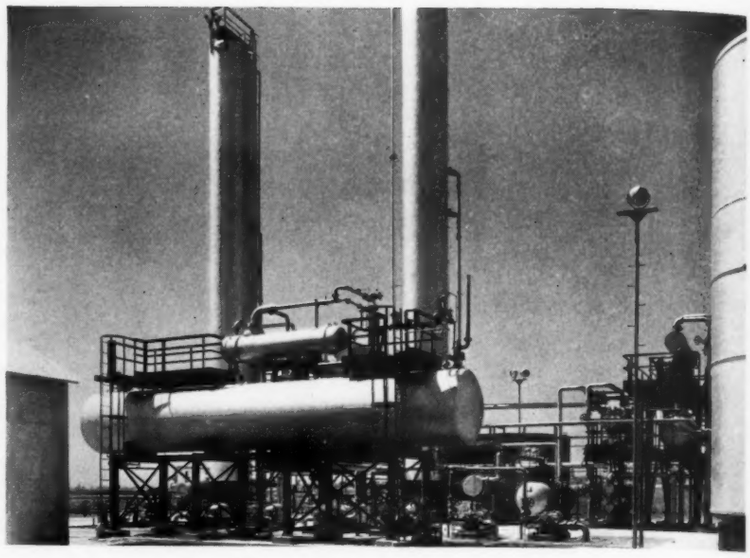
A new entry in the list of countries having a domestic refining industry is Siam, where the Japanese firm Mitsui Bussan Kaisha has concluded a contract with the Siamese government for construction of a refinery at Bangkok with a daily capacity of 500 bbl. of crude. The plant is designed to meet Japanese naval specifications as to output and will include a cracking unit for the production of high octane aviation fuel.

Construction activities in Japan and developments in the Japanese refining situation are discussed in a separate article on other pages of this issue.


REFINING TECHNOLOGY
Expressed by Alco Products

REFINERY TECHNOLOGY Concentrates on Production of 100 Octane Motor Fuel

Demand for High Octane Aviation Fuel So Far Exceeds Supply as to Constitute a Challenge to Refinery Research. Demand to Be Met by Super Fractionation and Pyrogenesis of Gases, Polymerization and Hydrogenation.



Recently completed tropane recovery plant on the Pacific Coast.

IT IS, PERHAPS, interesting to almost everyone to learn more about where the new 100 octane fuels are coming from, how they are made, and why they are not prohibitive in price. We first turn to chemistry and pay our respects for the accomplishments that have been made possible by the application of chemistry along with some physics. Without this work we would have no 100 octane fuel today at a price which would be low enough to make possible the large scale use of high octane fuel in cars and planes.

Aside from present sources of aviation gasoline, used with lead, and aromatic blends, there appear to be only two other commercial sources at the present time: (1) technical isooctane and (2) isopropyl ether. The only commercial source of isooctane at present is petroleum cracking still gases.

It is not considered necessary to go into details at this late date about the manufacture of isooctane on a commercial scale. It may be of interest to say a word or two about the general scheme.

First, it is necessary to obtain isobutylene and this is most economically done at present by fractionating cracking still gases to obtain a reasonably pure cut of the butylenes, normal and iso. Two isobutylene molecules are joined by polymerization to form a molecule twice as large, diisobutylene, and which boils above ordinary temperatures at atmospheric pressure. Two hydrogen atoms are then added to give the liquid, isooctane, or more correctly speaking, 2-2-4 trimethyl pentane, to distinguish it from less valuable isomers.

More important than this simple fact is that not all the cracking gases consist of this material; the valuable constituent is one individual hydrocarbon found therein; isobutylene. The constitution of cracking still gases from various cracking systems is quite well-known and the volume produced per day has been fairly well estimated. It is not difficult then, since we know the efficiency of present isooctane producing processes, to calculate the total ultimate production of isooctane from this source. Here again economics enter the picture and we can safely say that the future of isooctane as an aviation fuel is dependent upon two factors: (1) what it will cost to produce this material (per gallon) and (2) what will be the cost of competitive fuels made from aromatics or from other materials? And when values are established we then come down to the important link in the chain—the consumer. He has to ascertain how much an octane is worth to him insofar as it relates to his income from his engines which use the fuel. He will sooner or later arrive at a true value of each octane—if 100 octane fuel costs 25 cents per gallon and 87 octane fuel costs 10 cents per gallon, he will have to show earnings in proportion to his fuel costs. It may well be that he cannot show earnings enough to justify the high octane fuel. In this case, if isooctane cannot be produced at a cost which will allow it to be sold at 15-18 cents per gallon, its use will be restricted to military or other emergency uses where the cost of the product is secondary to its availibility at almost any cost.

It is possible that other chemical compounds will become available for aviation fuel such as would be obtained by joining either normal butylene with a molecule of another hydrocarbon and resulting in satisfactory octane value and other characteristics suited for aviation fuel uses. These predictions or assumptions are all entirely possible of consummation.

COST OF AROMATIC PRODUCTION

Fairly reliable data are now available which indicate that aromatic distillate can be commercially produced from either crude oil or from cracking still gases for as little as 7-8 cents per gallon.

The yield of such aromatic distillate when produced by thermal polymerization of cracking still gases (or from saturated gases containing not more than 4 carbon atoms per molecule) is roughly 60 percent of the yield of polymer blending gasoline as currently made with an octane value (net)

We are indebted to Dr. M. B. Cook of Alco Products, Inc., and also to Messrs. H. R. Swanson, J. W. Throckmorton and A. W. Hayford of Alco Products, Inc., and Mr. Cary Wagner of Pure Oil Co., for the information contained in this article and on the following pages of this section.

of 78-80. It is also fairly well established that the three common aromatics, benzol, toluol, and xylol account for about 70 percent of the distillate.

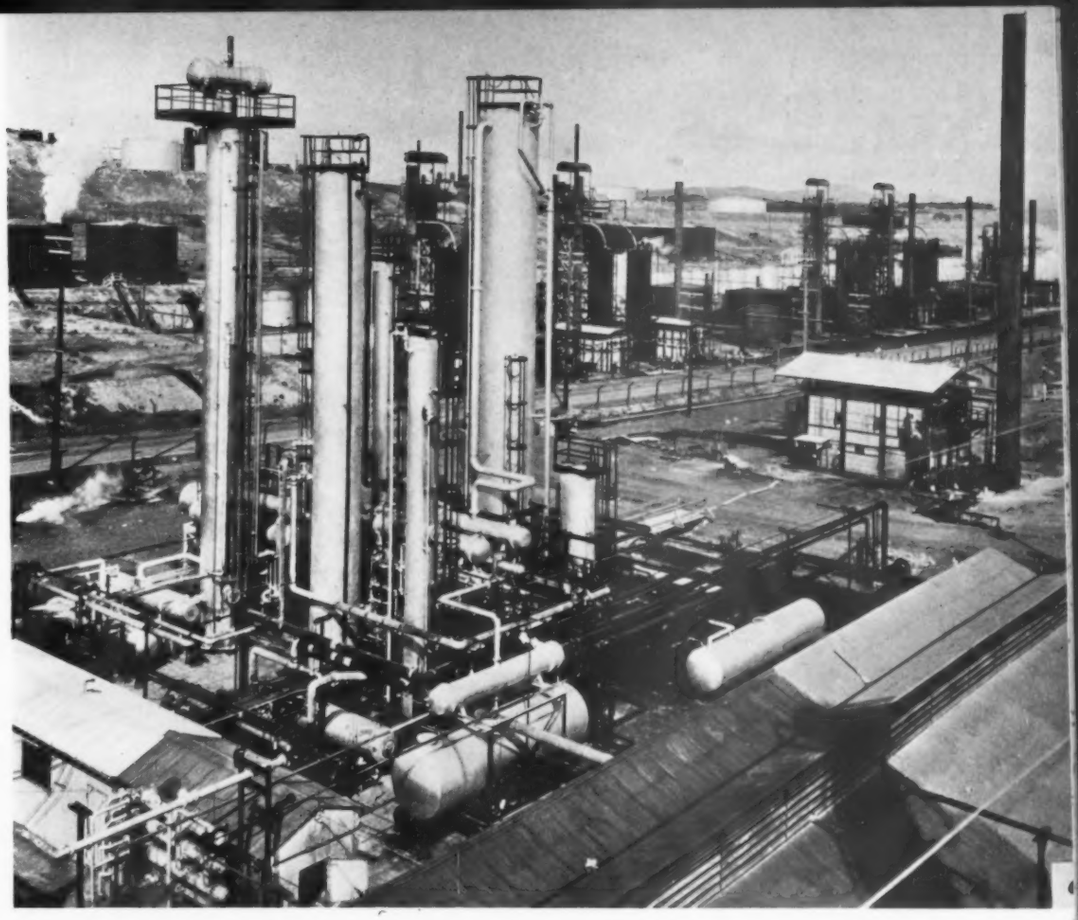
If we obtain our aromatic distillate as a by-product of high temperature cracking of gas oil or other charge stock containing more than five carbon atoms per molecule, a very interesting result is obtained, i.e., the aromatic distillate contains 85-90 percent of the three common aromatics and not 70 percent. Since this material necessarily contains a greatly reduced percentage of unsaturates it is entirely possible that this material will show up more favorably in aviation blends. It also follows that it is much easier to separate the three main aromatics from this distillate than it is to separate them from the 70 percent aromatic content distillate.

The explanation of the difference in aromatic content of the two distillates is to be found when we study the conditions existent in each process—the lower aromatic content distillate is produced at 1200 deg.F and 250 lbs. pressure whereas the higher aromatic distillate is produced at 1350 deg. F. and 15 lbs. pressure. The latter conditions are more favorable for aromatic formation so far as concentration of aromatics is concerned, but lower yields are obtained. The explanation of this is to be found when we consider what hydrocarbons are transformed into aromatics and what is the speed of the reaction. We can assume that ethylene, when held under pressure at elevated temperatures, is prone to form liquids other than aromatics. When ethylene and lighter gases are quickly and continuously removed from the sphere of action (allowing propylene, butylene, and butadiene to react) the heavier unsaturates polymerize rather rapidly to aromatics, with other polymer products forming to a lesser degree.

AIR COOLED MOTORS—AROMATIC BLENDS

Air cooled engines depreciate aromatic blend fuels more than liquid cooled engines do, and this depreciation is no doubt due to the high operating temperatures, although the design of the engine exerts quite an influence on the depreciation of such fuels. To prove the point of operating temperature and its effect, engines have been artificially cooled by external compressed air, and as the effectiveness of the cooling increases the depreciation of the aromatic blend fuels becomes less severe.

It is believed that previous test work on aromatics has not told the whole story about aromatics. As an example, very little work has been done on pure aromatics except in the case of benzol. Most of the aromatic blends have contained quite appreciable percentages of unsaturates and at times gums and resinous deposits have given trouble. It is felt that most of the gum and resin troubles encountered have been due to the unsaturates and not to the aromatics. In fact, it is not considered possible to decompose aromatics in an engine to give gum and resins. Another point which is still debatable is the question of which unsaturates give trouble and which do not. About two years ago, one of the major oil companies made up an aviation gasoline, the principal ingredient of which was cracked gasoline, which it is known contained a high percentage of unsaturates. The fuel rated very well in comparison with regular aviation gasoline containing lead but no unsaturates. The cracked fuel was stable in storage and appeared so promising that the Fuels Committee has requested that other manufacturers submit samples of their aviation cracked gasolines for tests. This is recommended so that more than one cracking process will be available to supply such fuels in case of war or other emergency. The engine used for these tests was a JAGUAR made in England, and the octane number of the fuel was 80 CFR Motor Method. This work is recorded in the Transactions of the S.A.E. (1936). The JAGUAR motor was a twin row, air cooled radial. Other cracked gasolines for aviation are now being studied.



Iso-octane is produced in appreciable quantities in this modern California plant.

It is our opinion that:

(1) Fuels rich in aromatics obtained from crude oil by distillation (Borneo) have been the main aromatic content fuels tested.

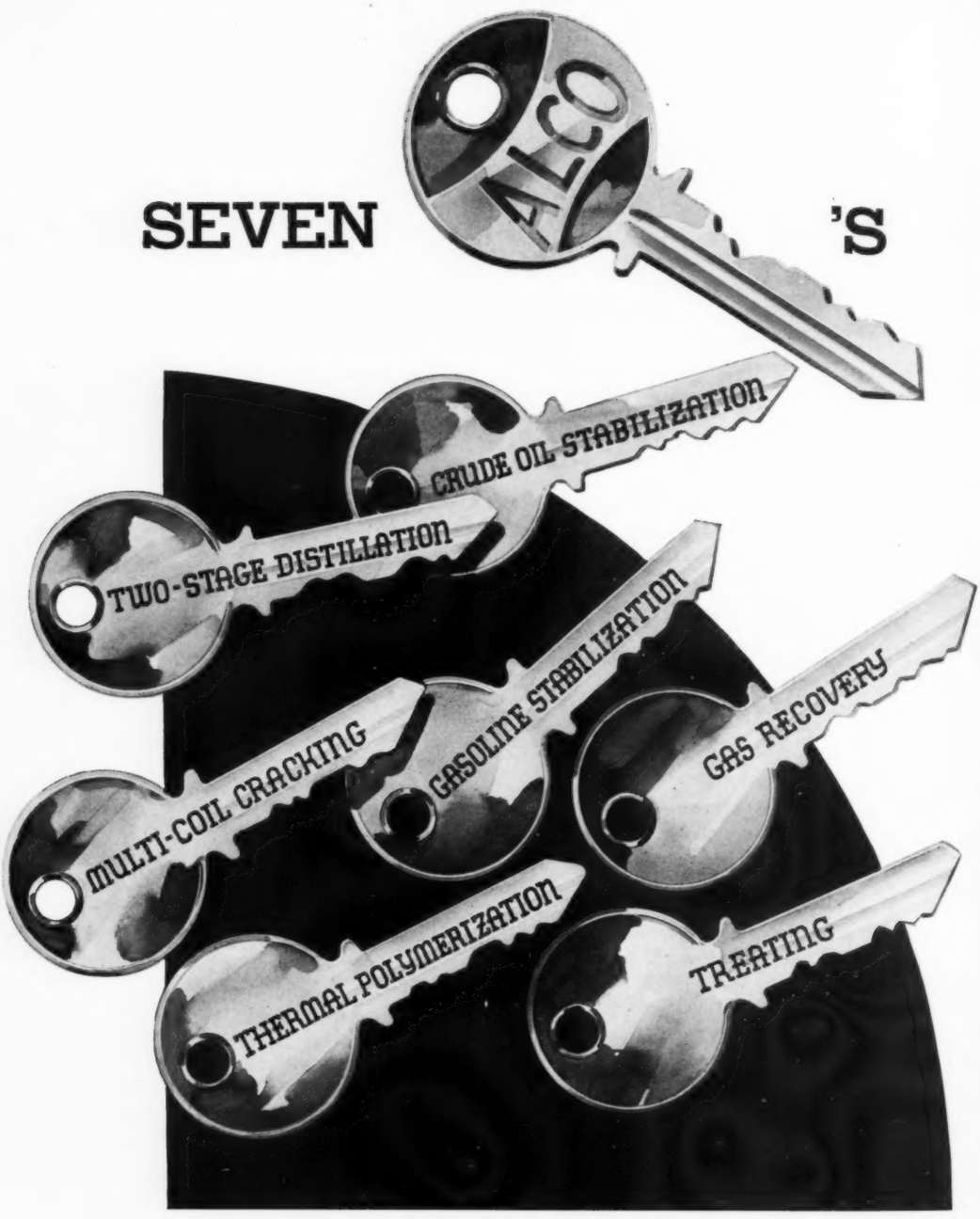
(2) Very little full scale engine test data on straight run—aromatic addition blends have been obtained.

It is further believed that the latter work should be studied in detail as it holds great promise of success.

ENGINE TESTS

It is well known that full scale aviation engine tests require large amounts of fuel and are expensive. It is, therefore, considered better policy to run small samples of differing aromatic content fuels in a one cylinder high-output test motor. By doing this work first it is certain that the blends will be evaluated, so far as promise is concerned, but no data on head temperature rise and deposition of gum on valves will be obtained. It is therefore necessary to follow this work by full scale aviation engine test work.

Recent work on a one cylinder high-output engine has indicated that most remarkable power outputs can be obtained from toluol-straight run blends when run in an engine properly designed and liquid-cooled. As an example, one test was made on a one cylinder high-output engine with very high supercharge. When run on the regular aviation gasoline (straight run with lead) the Brake Mean Effective Pressure


SEVEN
'S
ALCO
CRUDE OIL STABILIZATION
TWO-STAGE DISTILLATION
GASOLINE STABILIZATION
MULTI-COIL CRACKING
GAS RECOVERY
THERMAL POLYMERIZATION
TREATING

TO REFINERY *profits*

CRUDE OIL STABILIZATION conserves valuable low boiling point hydrocarbons, and reduces fire hazard.

TWO-STAGE DISTILLATION recovers a higher percentage of high viscosity lubricating oil.

MULTI-COIL CRACKING increases the yield of higher octane gasoline.

GASOLINE STABILIZATION assures uniform quality, and automatically recovers low boiling point hydrocarbons.

THERMAL POLYMERIZATION produces aromatic type polymer gasoline—an excellent blending stock in the production of high octane gasoline—and increases the gasoline yield per barrel of crude.

GAS RECOVERY conserves low boiling point hydrocarbons, and greatly reduces refinery fire hazard.

TREATING produces superior products and decreases losses.

ALCO PRODUCTS

30 CHURCH STREET, NEW YORK, N. Y. *Inc.* ARTILLERY HOUSE, ARTILLERY ROW, LONDON, S. W. 1. ENGLAND

DIVISION OF AMERICAN LOCOMOTIVE COMPANY

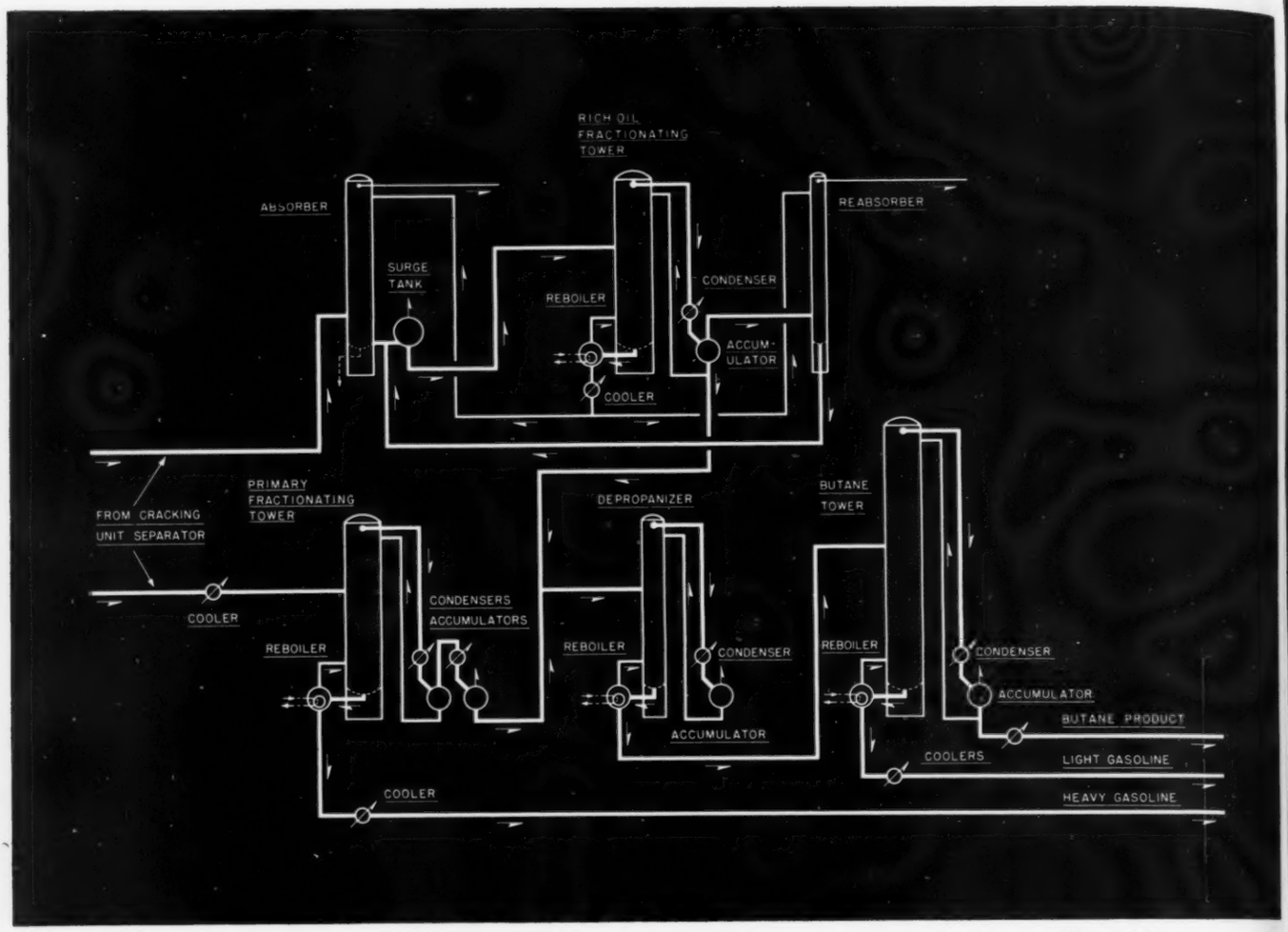


Figure 1-1.

was 200. When run on the toluol blend, a B.M.E.P. of 540 was obtained. This is the first work which has been reported which indicates the toluol blend to be capable of power output greatly in excess of the regular aviation fuels. This work further indicates that toluol is superior to benzol when used in blends.

The Canadian Research Council is now co-operating with the Co-operative Fuel Research Committee of the United States in exploring the possibilities of aromatic blends for aviation work.

Reports indicate that aromatic blends are being used successfully in certain steam cooled British aviation engines. This information appears to check the single cylinder engine experiments in that it has been found that the operating temperature of the engine must be kept down if the superiority of the aromatic blends is to be attained.

Considerable confusion appears in the minds of different investigators as to the value of air cooled versus liquid cooled motors. It is our belief that the air cooled motors offer no power possibilities superior to liquid cooled engines and the power output per pound weight of the motor is no greater. Their only major advantage appears to be one of "faith"—faith based on the fact that there are no liquid lines, pumps, gaskets, etc., on the cooling system to fail in long flights, particularly where great distances over water are to be flown. In other words, to quote a well-known aviation authority:

"There is less plumbing to get out of order in the case of the air cooled job."

Another set of test data, obtained in this case on an air cooled motor, showed that a benzol blend made up to 80 octane and run in a full scale engine was definitely better than an 80 octane fuel made from the same petroleum base stock by adding lead. In the case of the 87 octane blend, however, the reverse was true. This work indicates the possibility of making blends from aromatics and straight run gasolines which are superior to present aviation leaded fuels. In order to make use of this superiority, it will no doubt be necessary to change engine design and operating temperature for the higher octane fuels (above 80 octane).

The importance of this work cannot be overestimated, in our opinion, for it opens up a huge possible supply of aviation gasoline hitherto not available. The main reason for this appears to be the enormous possibilities of aromatics from petroleum, not to mention those which are regularly obtained from coal.

It should not be forgotten that the new source of aromatics will produce a result which is all important to the economics involved, i.e., if aromatics were obtainable only from coal, as has been the practice in the past, and the work contemplated proves that aromatics are highly desirable for aviation fuel blends, serious hardships would be placed upon the solvent industry and upon all present consumers of aromatics.

With the present successful commercialization of producing aromatics from petroleum and petroleum gases, as raw material, there need be no serious disruption of the current solvent business. The most important point to be gained from the present studies is that of enlarging our aviation fuel base. It is well-known that there is a none too great supply of 73-74 base aviation gasoline, because this material has been selectively separated from selected crude oils and from sweet natural gas. As aviation

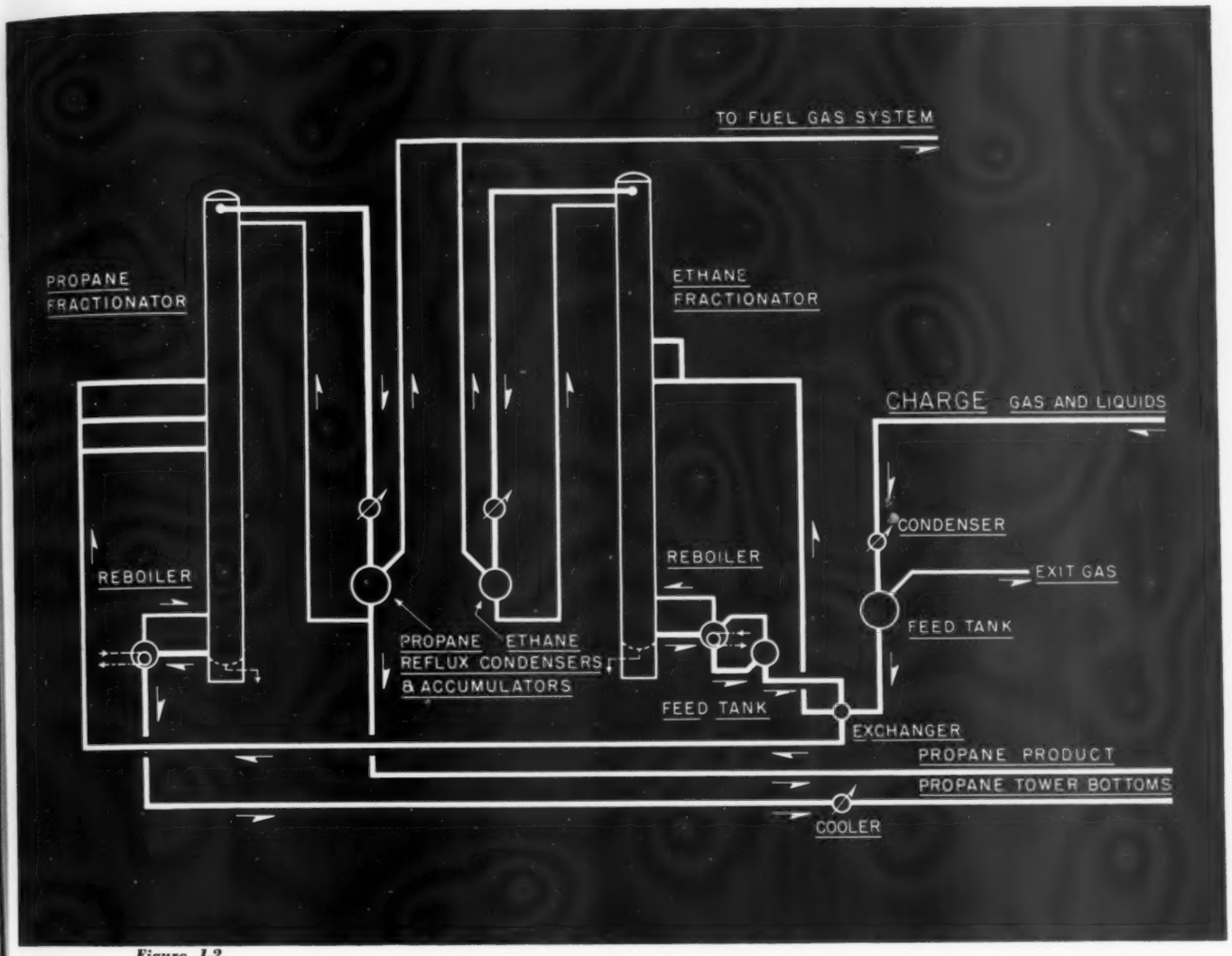


Figure 1-2.

grows there will be a great increase in demand for this selected base stock gasoline in order that lead can be used effectively. With crude oil demands increasing by leaps and bounds for automobile gasoline, it is well within the realm of possibilities that a shortage of 73 octane base gasoline fuel will occur even in peace times, not to mention what will happen in case of a national emergency.

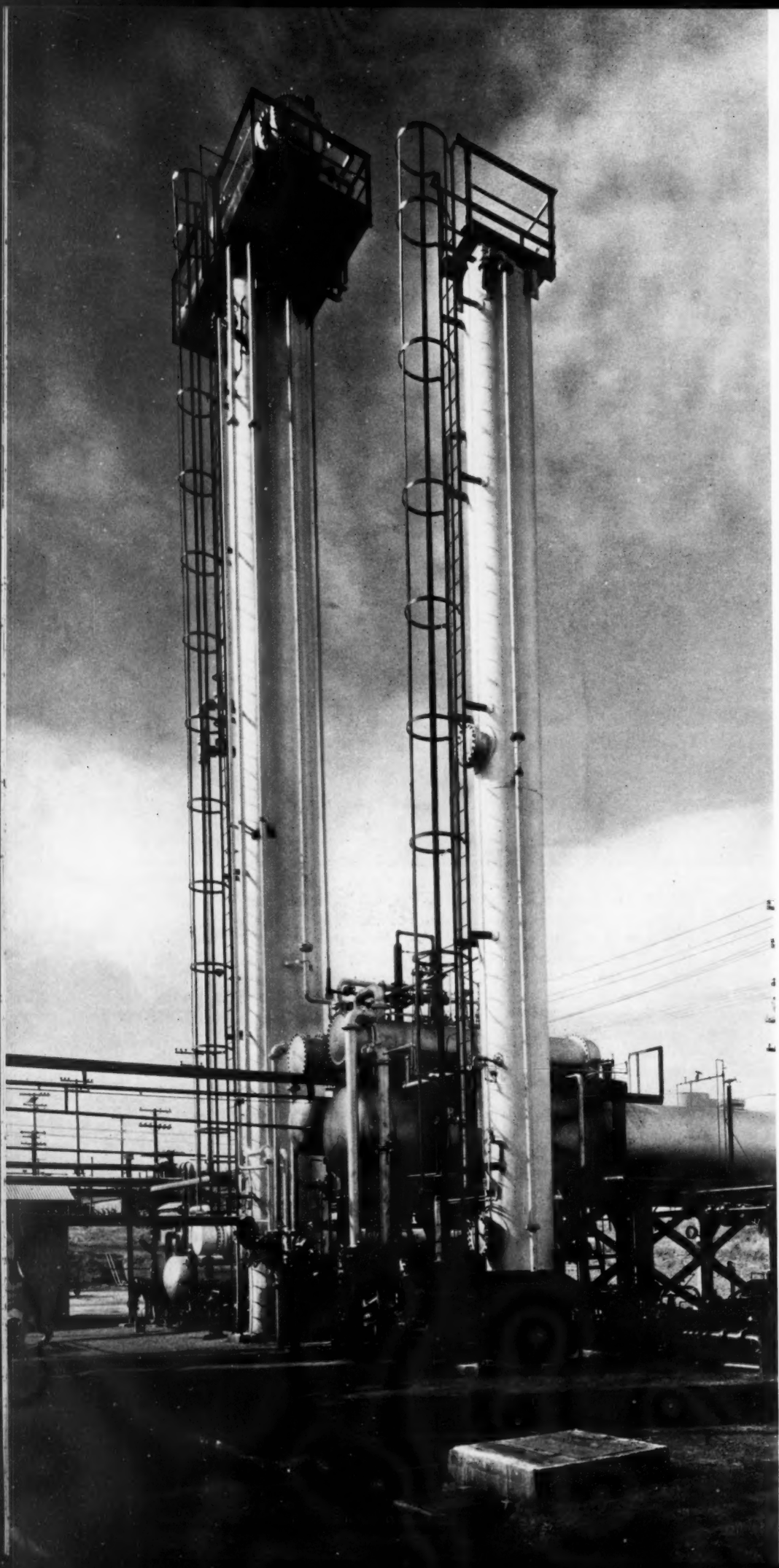
HYDROGENATION OF AROMATIC DISTILLATE

Work carried on in the past and other projects now under way indicate that high octane aviation fuel can be made successfully by subjecting the polymer distillate, or fractions thereof, to mild conditions of hydrogenation, thus forming principally the cyclo paraffins. Work of this character is being slowed up due to the fact that no satisfactory correlation between single cylinder octane test methods and full scale multi-cylinder engines is available. High octane fuels will be found more rapidly when this important work has been completed. It is almost impossible for individual companies to see their way clear to produce the rather large quantities of each theoretically promising fuel required for full scale multicylinder engine tests.

It is believed that not only hydrocarbon compounds containing 8 carbon atoms to the molecule but also those containing 9, 10, and 11 carbon atoms will be found to be excellent aviation fuels. To produce several thousand gallons of a compound such as tetramethylhexane for example, is an expensive and time-consuming experiment. If satisfactory small scale test methods and equipment were available, the task would be rather simple.

ISOOCTANE PRODUCTION

Alco Products has been a pioneer in the commercial development of isooctane manufacture in connection with the first step of the process, i.e., the concentration and separation of what is commonly called the B-B cut. It is known that isooctane is produced from isobutylene which in turn is obtained from gases and liquids which have been emitted from some pyrolysis operation carried out on hydrocarbon material. The B-B cut or fraction is obtained in the majority of cases from the stabilization of cracked distillate and from cracking still gases. Processes that will accomplish satisfactorily the results desired must be very highly developed in order to recover the maximum possible percentage of butylene and at the same time to separate clearly the propylene-propane cut from the B-B cut. Plants to produce such closely fractionated fractions have to be so designed that the (light) pressure distillate, after the stabilizing operation, will show less than 1.5 percent by weight of the butane-butylene fraction, and at the same time produce a butane-butylene fraction containing not more than 2 percent by weight of propane and 0.7 percent by weight of pentane. Recovery of the butane-butylene from the liquids and gases carrying such material is over 90 percent.

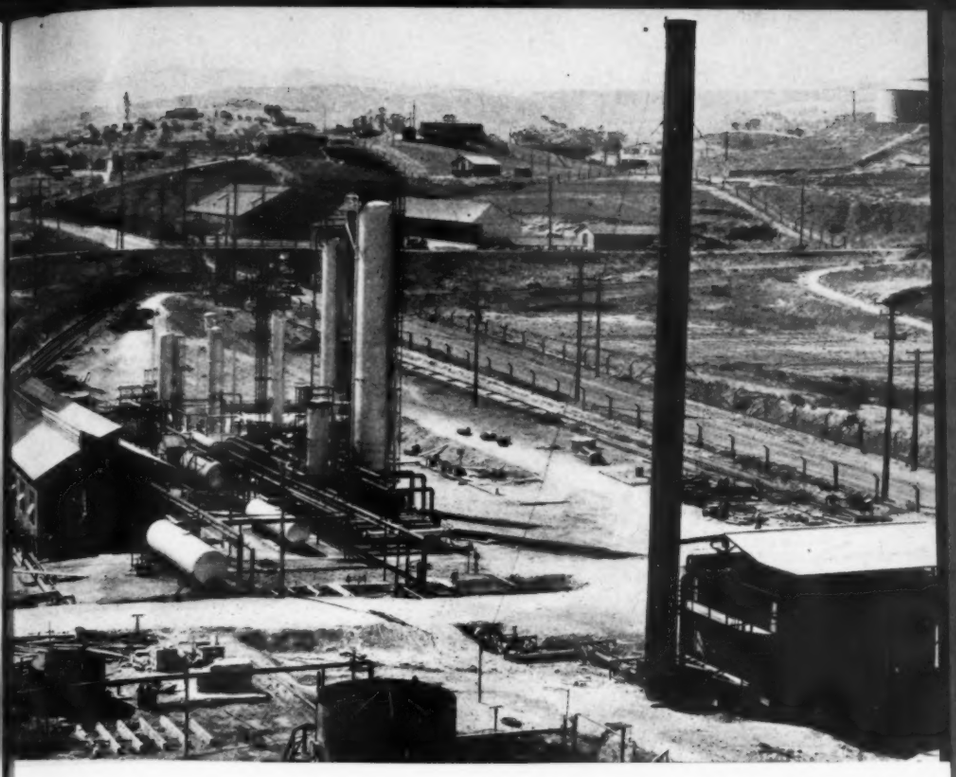


Very large cracking installations are required to produce enough by-product isobutylene in quantities sufficient to make the installations of an isooctane plant commercially feasible. As an example, there are required about 100,000 bbl. daily charge capacity of cracking in order to produce enough B-B cut (butane-butylene) to result in the production of 1000 bbl. per day of Technical isooctane by present processes. The figures are based on average liquid phase cracking unit conditions and of course do not hold true in the case of vapor phase cracking installations. In this case, the yield of the B-B fraction is much higher than from liquid phase cracking units. Work now in progress for increasing the amount of isobutylene as raw material for isooctane manufacture is mostly based on dehydrogenation of butane to butylene. If successful, this will make available large quantities of butylene and will tend to broaden the scope of isooctane possibilities.

The production and separation of propylene-propane cuts is usually carried out in the same plants as is the separation of butylene-butane. This process fits in very well since the liquids and gases must be handled under pressure in order to effect the desired separation and it costs little more to install towers and auxiliary equipment to separate the C_3's at the same time. Since this scheme is about as economical as it can be made, the thought suggests itself that if isopropyl ether and isooctane can be produced at the same time, the maximum in economy and flexibility is attained.

Processes are known for the production of isopropyl alcohol and isopropyl ether which permit the removal of propylene chemically, and the lighter olefin, ethylene, is unreacted. This makes possible the recovery of the three principal unsaturates, butylene, propylene, and ethylene from refinery distillates and gases in one continuous operation without a recompression of the gases. After the propylene extraction, the ethylene gas, associated with saturates, is usually pure enough to permit it to be used for chemical conversion to other and more useful products. While ethylene is not at present particularly adapted to conversion to aviation gasoline it can be made to serve another useful purpose for aviation and automotive fuels by converting it to ethyl chloride, ethylene dibromide, ethylene dichloride, all of which are used in quite large amounts in connection with the production of tetraethyl lead. It is also the practice now to convert ethylene to ethylene glycol to serve as a very good antifreeze for radiators in motor cars and in

Polymerization is another stage in the oil refiners' trend to manufacture synthetic resins and other chemicals from cracking gases.



Details of two extremely modern units in a California refinery.

liquid cooled aviation engines. Other industries are now finding that ethyl chloride and other derivatives of ethylene, propylene, and butylene make excellent solvents and large quantities are being consumed. Mention has been made of the possibilities of producing synthetic resins. According to figures published a short time ago, over 100,000,000 pounds of acetic anhydride were used in 1936 for the manufacture of resins and plastics. There has also been produced large quantities of acetone from unsaturated petroleum gases.

Most of the foregoing statements as to processes of obtaining the three normally gaseous unsaturates are predicated on the assumption that by-product cracking still gases are the raw material. Work during the past few years has been carried on to ascertain the possibilities of obtaining the normally gaseous unsaturates as main products and not as by-products. As an example, ethylene is now being produced from saturates by pyrolysis of the saturates followed by high pressure rectification of all gases produced by this operation. As much as 45 percent by weight of ethylene is now being obtained commercially from the pyrolysis of propane and butane. Since this process has worked out so well attention has been directed to the production of propylene as the principal product of the decomposition of saturated gases. By changing the operating conditions in the pyrolysis step, it is now possible to obtain over 20 percent of propylene along with ethylene and butylene from saturated gases. Considerable interest is now focused upon the large scale production of ethylene which can be converted to ethyl alcohol. With prices of agricutural products such as corn, potatoes, and sugar on the rise, ethyl alcohol from petroleum is now on the market. In certain countries and even in this country, isopropyl alcohol and acetone from propylene now offer attractive returns on the investment necessary for such plants.

OTHER SOURCES OF AVIATION BASE GASOLINE

In anticipation of probable shortage of high octane and high lead susceptibility straight run gasoline, various investigations have been carried out regarding possibilities of obtaining such material from naphthas from paraffin or mixed base crude oils. It is known, as indicated in the many articles in the literature today, that most straight run gasoline contains some high octane value constituents in mixture with low octane constituents boiling very close to the high octane ones. In order to attain separation of these high octane constituents in a high state of purity by fractionation, fractionating columns containing a very large number of bubble trays would be needed and furthermore, high reflux ratios, and hence high fuel consumption, in the columns would be required. It has been found, however, that concentration of these high octane constituents may be effected by columns of practical size and by the use of reflux ratios which are not impractical. Thus, by practical close-fractionation cuts of high octane number may be segregated which can then be blended together to produce appreciable amounts of aviation base stock gasoline suitable for leading.

A survey of crude oils reveals that from 10-35 percent of 74 octane base stock can be

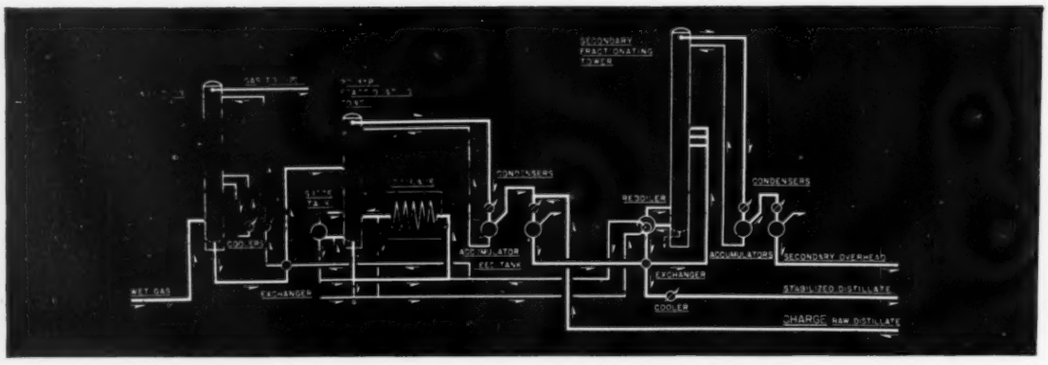


Figure I-3.

obtained by this procedure. The adoption of this process will serve two purposes. It increases the total available base stock for "leading" to 80 or 87 octane aviation gasoline, and (2) it opens up a source of aviation blend stock to individual refiners who are not fortunate enough to have a supply of such material from special crudes, such as Borneo, California, Gulf Coast, Baku (U.S.S.R.) or other naphthene stocks. Most all refiners could, by installing aromatic producing poly plants, obtain the desired boiling range aviation gasoline of high octane value if base blending stock of 73-75 octane were available at a competitive price. Superfractionation will, it is believed, serve to increase our aviation gasoline supply for some years to come. It is to be borne in mind also that such blending gasoline is required, as a general rule, in isooctane and isopropyl ether blends.

CHANGING CRACKING TECHNIQUE

Since over half of our motor gasoline now comes from cracking plants (including reforming of naphtha units) it is interesting to study the trends in the cracking art at present. During the past ten years it has been the goal of refiners to increase the liquid yields from cracking operations and decrease the gas production. This was logical, due to the increased earnings made possible by producing more gasoline. During the past two or three years, however, there has been a demand for increased octane value gasoline—which can only be obtained commercially by two routes; the one, higher temperature cracking and the other, by employing more lead. Consequently, cracking units have been installed with separate reforming coils, light and heavy gas oil cracking coils, and with separate vis-breaking coils. The primary purpose of these changes is to produce a higher octane product by increasing the temperature of cracking. This phenomenon is closely associated with gas production, as is well-known, consequently more gas is produced and the gases liberated carry increased amounts of unsaturates. Fortunately polymerization was developed in time to take care of the increased gas production, and it is now common practice not to worry about too much gas formation in cracking, within reasonable limits of course, for polymerization produces a gasoline with an octane value in excess of any and all straight cracking processes. In fact, the pendulum is now following the old law and is swinging to the opposite direction—more gas is being formed and more valuable gasoline is the result. As a matter of fact, the new combination of producing chemical intermediates such as ethylene, propylene, and butylene, along with aromatics by pyrolysis and by polymerization with the cracking operations as previously carried on in refineries, has resulted in a broadened horizon for all refiners; they can now go the limit on raising temperatures of cracking and not be penalized in earnings. The foregoing is predicated on obtaining fuel oil as one of the final products in a refinery. This combination, along with changing markets and the price structure of salable products is rapidly changing refiners' minds as to the desirability of changing their cracking operations from fuel oil operation to coking operations. A very fine article on the subject of economics of cracking and running to coke, written by Mr. J. B. Aug. Kessler and entitled "Balanced Utilization of Oil Products Needed," appeared in WORLD PETROLEUM, August, 1933. The facts set forth are actually more applicable to our situation today than they were four years ago. It appears now that running to coke in cracking operations will show more profits than running to fuel oil. This is indicated in spite of our increased knowledge of hydrogenation.

It is our feeling that the production of solids (coke) from liquid petroleum is wrong from a broad and nationalistic standpoint, since the known resources of solid fuels is many times the known deposits of liquids, and sooner or later the world will be forced to produce liquids from solids. It is therefore rather unfortunate that running to coke in refineries appears to be a necessity on account of markets and profits. It is regrettable that hydrogenation cannot be simplified, and consequently cheapened, so that low hydrogen liquid fuel oils can be converted economically to satisfactory internal combustion engine fuels. This would lengthen the life of our oil deposits and would result in a national gain. This problem is still with us, and it is believed that those who succeed in solving it will be rewarded for their efforts—cheap hydrogenation is almost a national demand and its solution should be in every technologist's mind until the goal is reached. This is a patriotic and national defense duty which is placed upon us all.

The trend of the refining, automotive, and aviation industries to higher and higher octane fuels has probably left its mark on the refinery equipment concerns more than on any other group of manufacturers. In order to develop these new fuels it has been necessary to carry on increasing amounts of research and development work for without added knowledge of the new conditions of operation, safety of the new plants would be jeopardized.

Manufacture of higher octane fuels has called first of all for gas and distillate stabilization plants, designed to finer tolerances both as to process and to mechanics than have ever been known before. This branch of refining is comparatively young and as the technique involved has been changing at such a rapid pace, one is more likely to see more pronounced changes in this part of a refinery than in other branches. Illustrative of these statements, a few of the newer super-fractionator gas plant installations are described. It is felt that the setting forth of the processes involved will give the reader a clearer picture of the complicated systems of refining whch are now fast becoming a reality. Since isooctane has been the most promising child of the 100 octane family, it may be apropos to start with the plants which have been developed lately to extract raw material from refinery gases to be used in its production on a commercial scale. It has been previously stated that the source of isobutylene, the raw material required for isooctane synthesis, is cracking still gases and untreated cracked distillates. Still more interesting is the fact that this material occurs in cracked distillates, in general, only to the extent of one to two mole percent. In other words, the material sought is present in extremely small quantities. Wet gas from cracking stills carries, in the case of liquid phase cracking units, about the same percentage of isobutylene. The problem then, for the equipment designer and process engineer, is to develop a process which will handle such lean material and extract the desired fraction efficiently and economically.

The most successful scheme for accomplishing the desired results consists of four operations:

1. Pressure Distillate Fractionation.
2. Absorption.
3. Depropanization.
4. Debutanization.

It is usually desirable to separate the pressure distillate into light and heavy gasoline and the latter to go to some kind of treating plant for finishing to suitable specifications. Light gasoline is charged to depropanizer for removal of propane and propylene.

The gases are contacted with absorber oil for the purpose of removing the major part of the butane-butylene and heavier fractions and recovering this fraction in the accumulator of the rich oil fractionator as a light gasoline which is pumped to the depropanizer.

The combined light gasoline from the foregoing operations is fractionated removing the propane and lighter fractions as waste gas while the bottoms flow to the butane-butylene tower.

The depropanized light gasoline is fractionated in the butane tower using adequate plates and reflux to produce a high degree of purity on the butane-butylene overhead product. Bottoms are washed with caustic soda in a treater tower, if necessary, and are usually then ready for blending with the treated heavy gasoline for the production of motor gasoline.

It is realized that the depropanization step is capable of rendering more service than a simple elimination of light gases, i.e., propane-propylene can be and is removed in some of the latest plants as a separate product in liquid state, and may be used as raw material for such compounds as isopropyl alcohol and the corresponding ether. If desired, ethylene can be extracted as a separate cut by installing the proper fractionating and compression equipment. From a design standpoint, it may be of interest to indicate the average conditions which a plant of the type must meet in order to be considered satisfactory for full scale operation.

A. The heavy pressure distillate product must show an ASTM initial boiling point averaging not less than the endpoint of the light pressure distillate product.

B. The light pressure distillate product must contain less than 1.5 weight percent of the butane-butylene fraction.

C. The liquid butane-butylene product shall contain not more than two percent by weight of propane and 0.7 percent by weight of pentane. The quantity of this product will contain not less than 90 percent of the available butane and butylenes in the combined charge to the plant.

The general process is indicated on the flow-diagram Figure I-1.

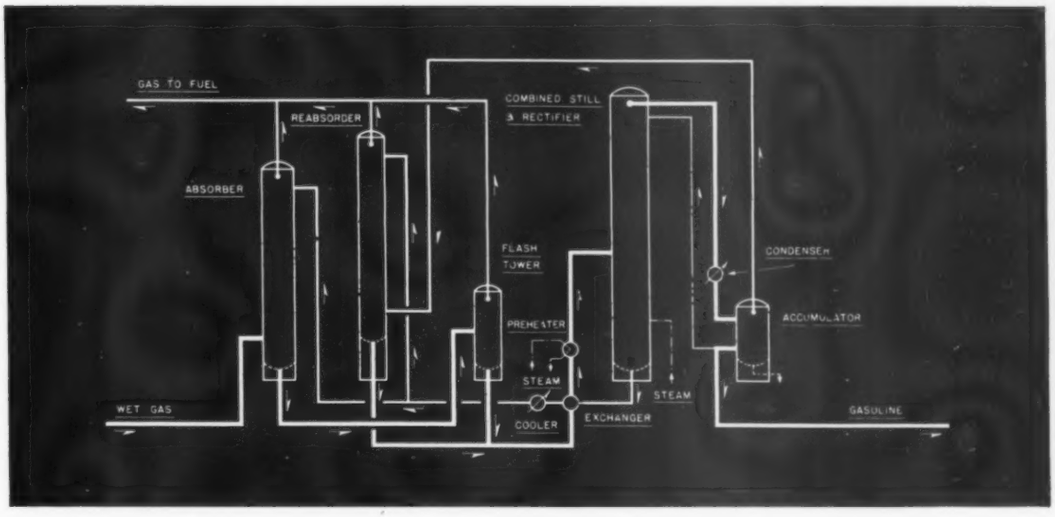


Figure I-4.

PROPANE-PROPYLENE PLANTS

Alco Products have designed and installed gas plants, including absorption and stabilization plants of the above type. The one plant is more properly designated a propane recovery plant since this product is the one sought. The plant works in conjunction with previously installed pressure distillate stabilizing units and absorption plants. Referring to flow diagram Figure I-2 the process operates as follows:

The raw pressure distillate passes in counter-current heat exchange against tower bottoms to the flash tower. A rough fractionation is made which puts overhead practically all the butane and lighter material. This endpoint is controlled by reflux. Bottoms from this operation flow through exchangers heated by cracking still residuum, through a steam preheater and are fed into the primary tower which cuts overhead the remainder of the 212 deg. F E. P. material which is totally condensed.

This condensate is pumped into the flash tower final condenser to aid in condensing the flash overhead. The mixture of primary tower and flash tower overheads flows into the flash tower final accumulator whence the uncondensed vapors pass to the propane absorber and the condensate is pumped into the ethane feed condenser where it effects condensation of the absorption plant product, the mixture flowing to the ethane tower feed tank. From this tank it is charged to the ethane tower where practically all the material lighter than propane is removed overhead to the residue gas line, or may be returned to the propane absorber, if desired.

Bottoms from the ethane tower flow by difference in pressure heads to the propane tower where the propane product is fractionated overhead. The bottom product is butane plus 212 deg. F E.P. light gasoline.

The propane absorber is operated to absorb about 65 percent of the inlet propane. The primary still is operated to strip sufficient light material from the fat oil so that the remaining absorbed constituents may be totally condensed in the secondary still condensers. Since total condensation is not obtainable in the primary still condensers, the uncondensed vapors and the condensate pass to the ethane feed tank when it is totally condensible in the presence of the light cracked gasoline.

The process shows the following advantages:

1. When it is desired to add propane recovery equipment to absorption and stabilization equipment already in use, no change in apparatus of existing units is (as a rule) required since new duties impose lower load on the pressure distillate fractionating units and loads well within the capacity of the absorption plant.

2. Use of the 212 deg. F. end point gasoline as an aid in condensing the flash overhead reduces the vapor or pressure distillate tops which must be handled and at the same time reduces the propane and heavier gasoline to about 10-15 percent of that carried by the vapors with no propane recovery plant.

3. The above reduction of vapors permits adequate recovery of the propane and heavier material in the existing propane absorber without the use of compressors.

4. Since the above vapors are treated by absorption which is largely selective in rejecting methane and ethane whereas compression includes the total vapor as feed to the ethane tower, the tower overhead quantity is less and contains less propane when comparative fractionation is obtained.

5. The absorption plant product is totally undesirable in the presence of the

Laying the foundations for a polymerization unit in southern Texas.

light gasoline fraction thus eliminating the necessity of compressing the uncondensed still vapors which are normally emitted.

ABSORPTION PLANTS

Alco Products designed and installed a modern plant which includes latest developments in absorption and fractionation. Referring to the flow diagram Figure I-3, the process operates as follows:

The wet gas enters the base of the absorber and flows upwards counter-current to the descending absorbent. The rich oil is pumped from the base of the absorber through the cold exchanger to the primary tower.

The primary tower fractionates the absorbed hydrocarbons from the lean oil. The overhead passes to the reflux condenser and reflux accumulator whence reflux is pumped back to the tower. The net overhead flows to the final condenser where total condensation is obtained with the aid of the 8,500 bbl. per 24 hr. of light gasoline. The net bottoms flow through the secondary reboiler, supplying heat to this unit, thence to the exchangers and coolers. Reboil heat is supplied by pumping the bottoms through the tube still and returning them to the tower.

The secondary tower feed is pumped through exchangers and discharged into the tower. The total overhead passes to the reflux condenser and accumulator whence reflux is returned to the tower and the net overhead flows to the final condenser. The bottoms pass through the reboiler, exchangers and cooler to storage.

Alco erected a plant in Texas, which is quite different from the older type plants for this class of work. It will be noted that the gas contains 97 percent methane and ethane—leaving only three percent of the desired materials to be extracted. Over 25,000,000 cu. ft. of gas are handled in this plant at pressures in excess of 750 lbs. Operations such as these have made engineers do a lot of thinking in order to make such an operation safe and economic.

Referring to flow diagram Figure I-4 the process works as follows:

The design of the plant is based on receiving the low pressure gas at the base of the absorber at 825 lbs. per sq. in. ga. and 90 deg. F.

The combined gases from the two sources enter an absorber operating at 825 lbs. per sq. in. ga. The absorber is designed to extract 97 percent of the butane and 100 percent of the pentanes and heavier hydrocarbons. Extraction of this high percentage of butanes results in the unavoidable absorption of large quantities of methane and ethane which present difficulties in the recovery of the prescribed quantity of liquid butane.

As the inlet gas to the absorber contains over 90 percent methane, it is extremely important that, if incorrect design of distillation equipment is to be avoided, the correct absorption factors for methane at elevated pressure be used in the absorption calculations.

As the quantity of methane absorbed is greater than the sum total of all other hydrocarbons absorbed, the distillation process must be carefully selected to vent from the rich oil before it reaches the still, the maximum amount of methane with the minimum amount of butane. The calculated quantity and quality of the vented vapors are greatly influenced by the methane deviation factors used and here again it is fortunate that test data on a similar plant is available. Venting temperatures and pressures have been carefully selected to minimize recycles and at the same time obtain the required liquid butane recovery. Calculations have been made over a wide range of temperatures and pressures. Cold venting has been selected mainly because, as actual vapor pressure of methane increases very little with temperature in comparison with the actual vapor pressure of butane, hot venting produces vent gas relatively low in methane and high in butane.

The rich oil from the absorber flows to a high pressure vent tank which releases gas containing over 85 percent methane and a small quantity of butane. This gas may be used as fuel.

The vented oil which still contains 40 percent of the methane absorbed passes to a low pressure vent tank which releases gas. This gas contains over 65 percent methane. The butane content, though relatively low, is high enough to warrant the return of this gas to a reabsorber.

Leaving the low pressure vent tank, the oil containing a small quantity of methane and practically all of the butane and heavier, is pumped through exchangers and preheater into the combined still and rectifier operating at 80 to 100 lbs. ga. The gasoline is stripped from the oil by steam distillation and passes to the condenser and gasoline water separator. A small quantity of uncondensed vapors is released at this point and returned to the reabsorber.

The vapor pressure of the product can be controlled at lower values with corresponding reduction in still pressure and increased uncondensed vapors recycled to the reabsorber. The reduction in butane recovery will depend on the feed to the plant at the time.

PRESTABILIZING PLANTS

A development of recent years has been the perfecting of stabilizing plants for handling crude oil before placing it in storage, for running to stills. Two very important points are gained by this process; the one is conservation of eight hydrocarbons, and the other is safety. The process also allows a producer to mix natural gasoline, recovered in the field with the crude and transport the mixture in one pipeline to the refinery. Vapor losses from intermediate storage, etc., are reduced to practically nothing.

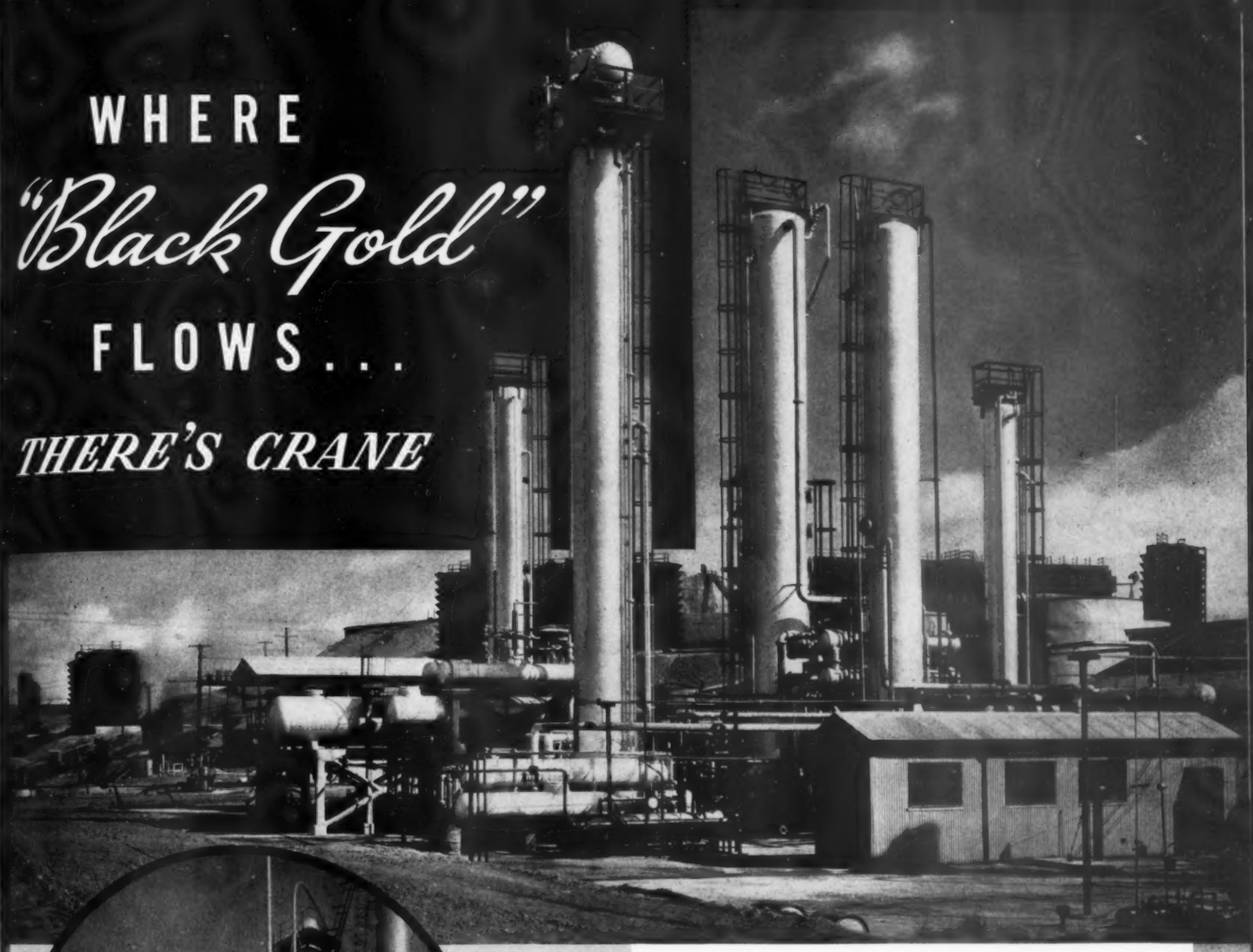
The process gives a maximum of flexibility to operation and at the same time permits independent control of the flashing system from the debutanizing system.

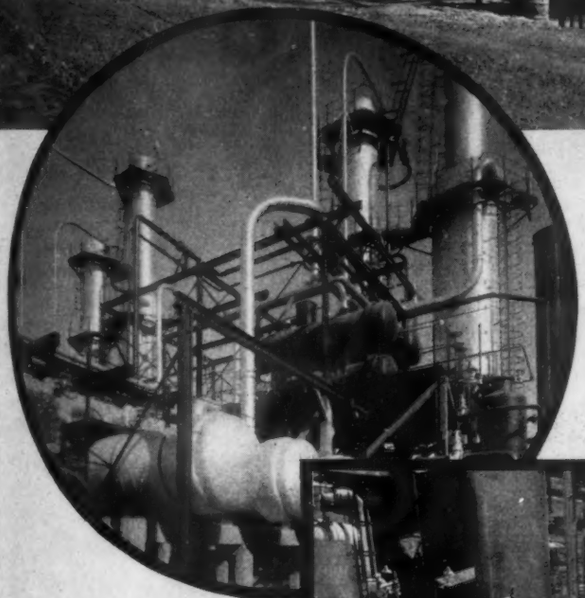
The crude charge is flashed in two flash towers operating in parallel. The end point of the overhead vapor is controlled by refluxing with a portion of the condensed overhead from the primary fractionator. The remainder of this condensed overhead is introduced into the flash vapor after cooling to effect total condensation. Separate condensers and accumulator tanks serve each flash tower to provide flexibility in flash conditions.

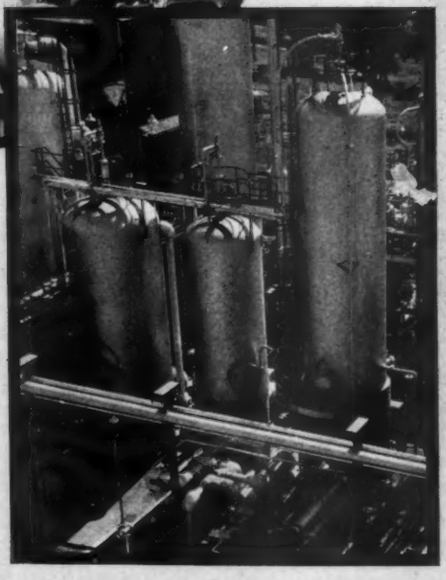
Large accumulators for the flash condensate are provided to assist in reducing rapid variations in the composition and charging rate of the debutanizer feed.

The debutanizer reflux is condensed in a separate condenser at approximately 120 deg. F, and the uncondensed net overhead is passed to the final condenser where it is cooled to 95 deg. F. for complete condensation. This method of condensing the reflux separately at a higher temperature results in an appreciable saving in condenser surface.

WHERE "Black Gold" FLOWS... THERE'S CRANE







● Modern refining technology is evidenced in the distillation plants engineered by Alco Products, Inc. Under the extreme conditions inherent in refining processes, Crane valves are proving their ability to regulate flow with an exactness that is a silent testimony to their excellent engineering.

Wherever "Black Gold" flows—whether it is in the near-by fields of Texas or California or the more remote ones of Russia and Iran—Crane has been selected on the basis of quality. In the field and pipe lines—in the refineries and distillation plants—Crane valves are recognized as the final answer to piping problems.

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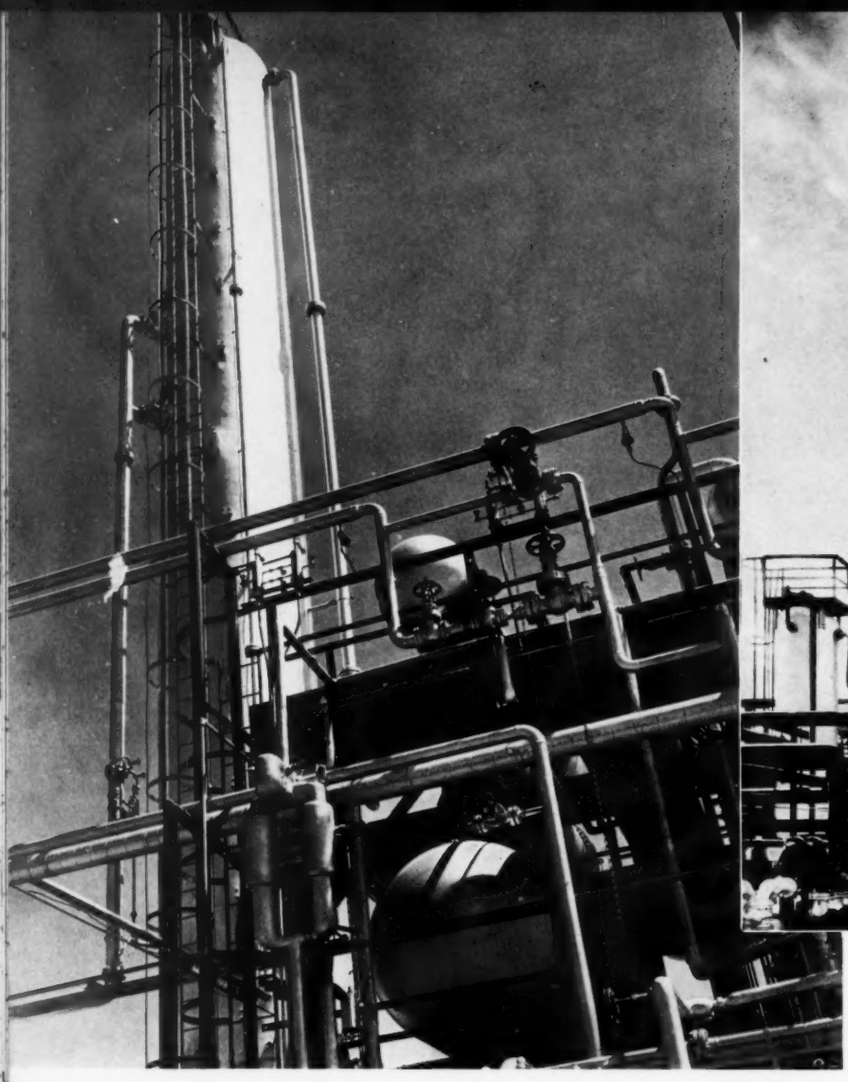

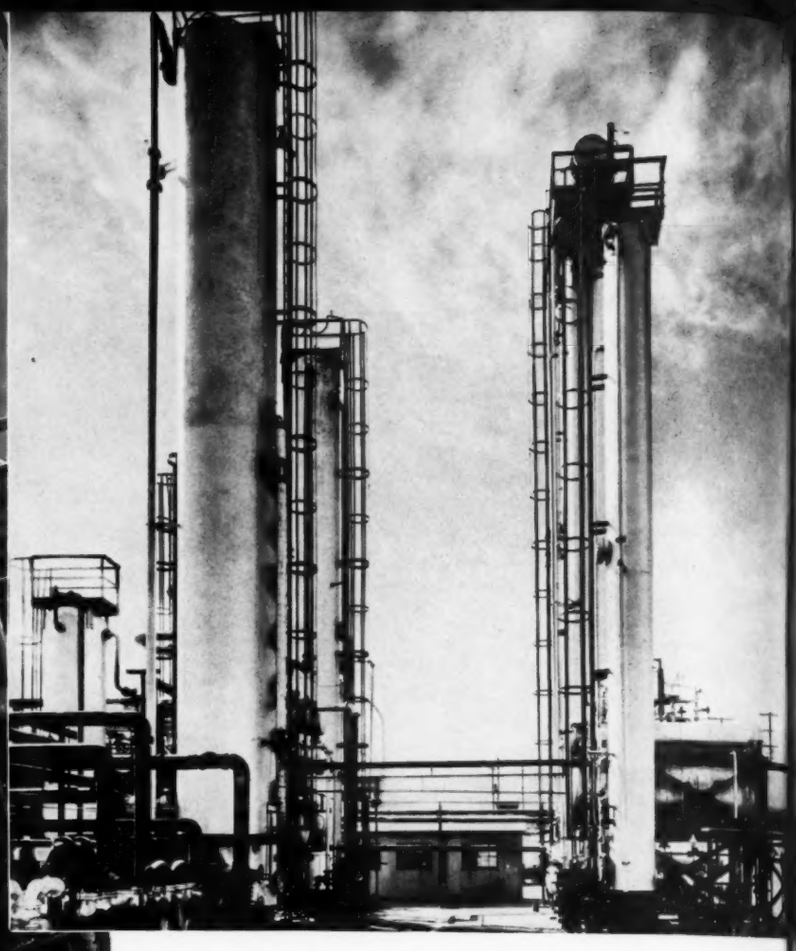

CRACKING GASES

Above 1300 Deg. F.

THE TERM petroleum refiner has a very definite meaning, at least to those versed in the art although in pre-war days he was better known as an oil boiler. He manufactured some chemicals, mostly for his own use, such as soaps for grease making. In the full sense, the oil boiler did not engage in chemical manufacture. The petroleum refiner, however, is now entering the chemical producing business. Many are manufacturing large quantities of sulphuric acid, paints, paint thinners, solvents for dry cleaning and degreasing of metals, rubber solvents, etc. He also produces organic solvents by the simpler physical separation processes which do not involve the use of synthesis.

Today, many refiners are interesting themselves in organic synthesis for petroleum gases or petroleum of their own production. On the other hand, some have already decided to dispose of their gaseous by-products to manufacturers of organic chemicals. Illustrative of the latter is the plant of the Carbide & Carbon Chemicals Corporation at Whiting, Indiana, which uses as raw material the by-product still gases of the Standard of Indiana. Between the two lies the question of whether or not the refiner should engage in the actual synthesis of organic chemicals. Each individual case, of course, has to stand on its own feet economically. Such matters as location of plants in relation to markets, the extent of available research facilities, and patent position are factors of influence.

To gain a better perspective of the problems of today among refiners, it may be well to discuss the past and present trends from the consumers' and refiners' standpoints.

Although the refiner has not been engaged in the manufacture and sale of organic chemicals, he has been a large consumer of such products, and he is quite familiar with the growth and development of some of them. The history of tetraethyl lead and of anti-oxidants is familiar to most of you. An understanding of the problems of the refiner and consumer, taken together with the facts relating to some of the developments which have already occurred, will doubtless indicate the future trends in this important field of activity.

It has been orthodox for the past decade, at least, to refer to the thermal decomposition of hydrocarbons by the general term cracking. Since this is broadly descriptive of the operation under discussion, it may be well to continue its use in speaking of the production of motor fuels such as gasoline from heavier oils such as gas oil or reduced crude oil. A new and rapidly growing branch of cracking now requires some descriptive term in order that we can easily distinguish gasoline production operations, by cracking, from the olefin-aromatic production. We prefer to use the term pyrolysis in the latter case. Production of olefins by cracking may be regarded as a purely by-product and incidental operation; since gasoline is the main product sought. We find that olefins from cracking gases are not in sufficient concentration to merit extensive separating plants for the segregation of high purity ethylene, propylene, and butylene.

It appears more economic to start out with lighter charge stocks, such as propane, butane, or light gas oil, and to aim for high conversion rates for the final recovery of the olefins mentioned. The step produced first is the one of application of heat—lots of heat to maintain conversion temperatures far in excess of the ordinary cracking still

operations. By this pyrolysis step, where we convert, for example, propane to ethylene, we use temperatures of 1,250-1,350 deg. F. and at the same time, lower our pressures from several hundred pounds down to one atmosphere or lower. By so doing, we cut down the time of conversion (the space of time the hydrocarbons are subjected to these high temperatures) and thereby greatly reduce side reactions such as polymerization. High yields of olefins are produced by this system of operation and low yields of liquid products are obtained; what liquids are produced are aromatic in character and have a higher value than the charge material. This operation is almost diametrically opposed to the usual cracking operation for the production of gasoline since the liquid formed as a by-product is black fuel oil and its value is always less than the charge stock.

Another step in the pyrolysis operation which is all important is the one of quenching with some liquid or gas—in direct contact with the pyrolysis products—so that instantaneous reduction of temperature is a fact. The time of the conversion at 1300 deg. F. for olefin production is one of seconds or split seconds, consequently we cannot pass our pyrolysis products through coolers where some barrier is existent between coolant and the material to be cooled. As we increase our conversion temperatures to such heights as 1,250-1,350 deg. F., the velocity of the pyrolysis is enormously increased over that at 900-925 deg. F., the temperature of conversion of most cracking units operated for the production of gasoline from heavier oils. This development opens up a whole new line of possibilities such as the recovery of propylene and butylene as by-products. Where ethylene is the main product, propylene and butylene are excellent charge stocks for polymerization.

The separation of ethylene is now a perfected industrial process and not merely a laboratory curiosity. From this type of operation there is obtained about 20 percent by weight of an aromatic distillate containing in excess of 85 percent benzol, toluol, and xylol. This material is now in demand as a high solvency naphtha and as a source of toluol itself as well as the other two aromatics, benzol, and xylol. At present market prices, it is estimated that 90 percent purity ethylene can be made from stabilizer overhead (light hydrocarbons) or from reduced crude for 1.5 to 2.0 cents per pound. The 10 percent impurity is ethane which does not interfere with the use of ethylene in most chemical processes. The yield of ethylene from stabilizer tops is about 50 percent and if gas oil is used as charge stock the yield is about 28 percent by weight. It is to be noted that this type of operation produces no gasoline as such—only gases, aromatic liquids and fuel oil. It is therefore not necessary for a chemical company to enter the gasoline business in order to obtain the unsaturates for chemical synthesis—no gasoline has to be sacrificed at whatever price it will bring for none is made.

If it is desired to make aromatics the main product from a pyrolysis operation, it is quite simple to follow the pyrolysis step by the Pure Oil process for polymerizing the gaseous hydrocarbon to liquid aromatics. This is more fully described under "Broadening the Scope of Polymerization" on page 90.

Striking floodlight picture taken at night of a new refinery in England.

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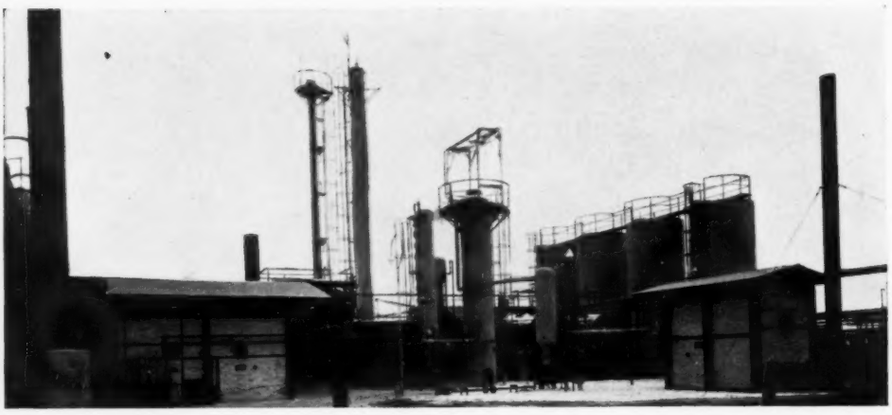
LOCOMOTIVE COMPANY

BROADENING THE SCOPE of Polymerization

A Thermal Polymerization Process Is Being Modified to Produce Di-Iso Butylene Which, on Further Treatment, Becomes Iso-Octane —Aromatics Produced by Polymerization Can Be Hydrogenated to Yield 95-100 Octane Motor Fuel.



One of the first commercial applications of polymerization in the United States.

THE REFINING industry has been fairly well informed during the past two or three years as to developments in polymerization. Numerous articles have appeared in the trade journals and a number of papers have been presented before the several technical society meetings. To recapitulate, the first commercial ploymerization plant was installed at the Toledo refinery of the Pure Oil Company and operated on refinery gases from Gyro cracking stills. This plant was installed for the purpose of obtaining high octane gasoline to be used as a blending agent with the regular straight run and cracked gasoline. This plant has been fully described by Cooke, Wagner, and Swanson, A. P. I., Los Angeles, California, 1935. The plant produced an aliphatic type poly gasoline which has an octane rating of 80 (net) and a blending value in excess of 100. Olefins, paraffins, and naphthenes constitute the major part of this polymer. It will be recalled that plants of this type operate at 900-1000 deg. F. and under several hundred pounds pressure. These conditions are conducive to the formation of alicylic hydrocarbons and are not well suited to the production of aromatics which require higher temperatures and lower pressures. Both olefins and paraffins in refinery gases are converted to liquid polymer of the general characteristics described above.

Other polymerization plants such as those of Universal Oil Products employing a catalyst, phosphoric acid, have been described and have as their main object, the production of aliphatic type liquid gasoline polymers. The essential difference between the thermal process of the Pure Oil Company and the U. O. P. catalytic plants is that the catalytic type convert only olefins carried by the charged gases to liquids but do not convert the saturated or paraffinic gases. Both types of plants are operated for the production of gasoline blending material but do not aim to produce material suitable for the solvent, paint, rubber, or general chemical syntheses.

The thermal system has been employed to produce aromatics from normally gaseous hydrocarbons, both from natural gas and from refinery gases.

Alco Products have installed several aromatic plants, some of which charge entirely saturated normally gaseous hydrocarbons, propane, and butane, and produce aromatic polymer liquid.

Alco installed such a plant for in the near East to charge liquid propane and butane for the production of aromatic liquid. This plant has the largest output of aromatics from petroleum hydrocarbons of any so far built anywhere. It produces over 500 bbl. per day of aromatics from natural gas hydrocarbons. The process is outlined in the flow diagram opposite, which is self-explanatory.

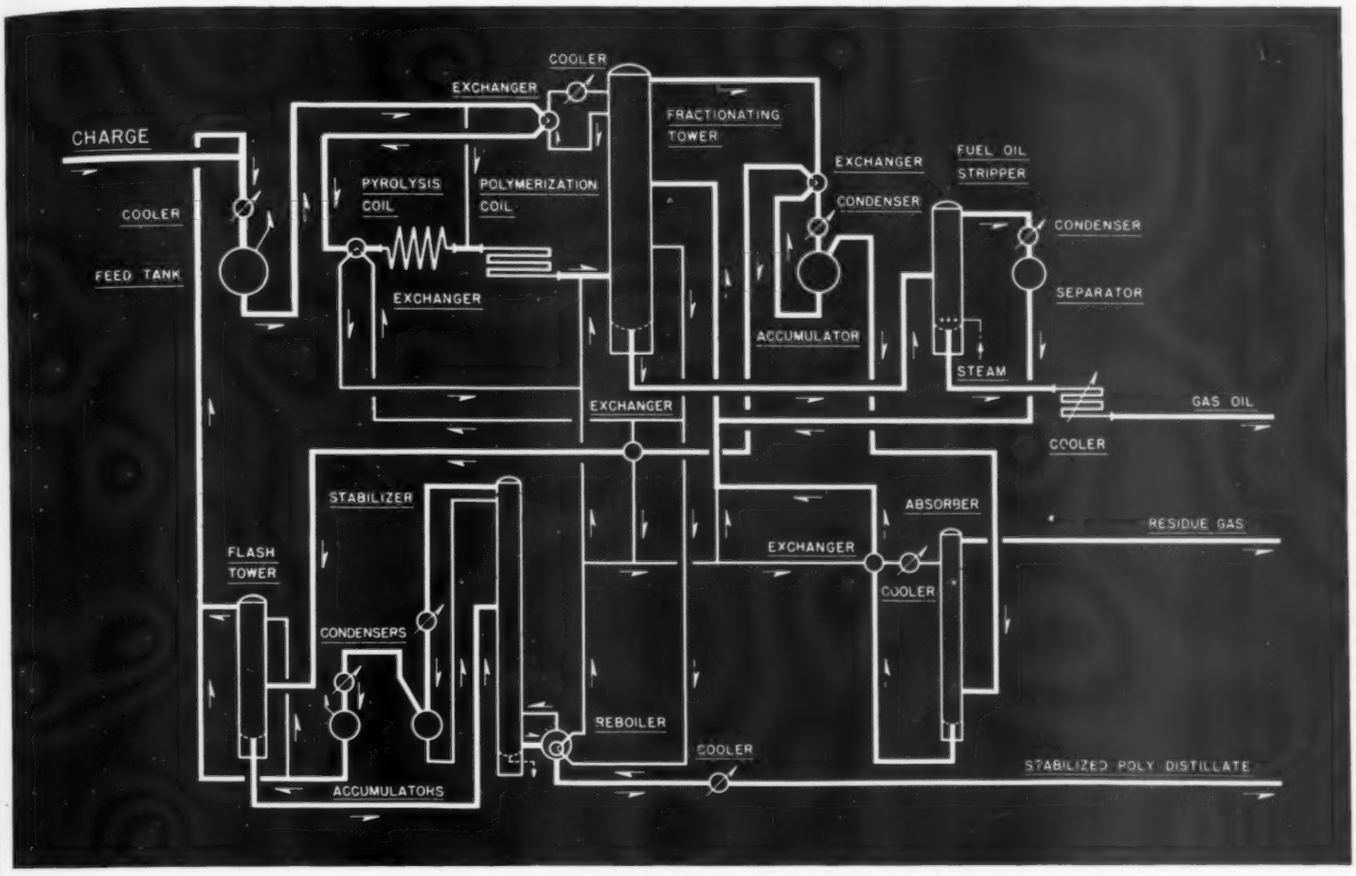
Each portion of the complete plant comprising the furnace, reaction coils, tubular units, fractionating towers and pumps, has a safety factor included which permits the plant to operate at varying pressures over a wide range.

Alco is installing a very up to date polymerization unit in California. This unit is a fine example of coordination of refinery units to give the maximum in gasoline yield with a maximum possible octane rating.

A number of refiners, it is believed, have problems almost identical with those being solved by the installation of this thermal polymerization unit. Practically everyone manufacturing gasoline today is equipped with pressure distillate stabilization units, gasoline recovery plants, either absorption, compression, or a combination of the two and of course cracking equipment.

The present installation is designed to use as charge stock liquefied fractions of low boiling point hydrocarbons obtained by the various units mentioned above. These polymer charge fractions are available from the various stocks and are based on the quantity in excess of requirements of these materials, normally required for inclusion in regular gasoline. A part of this charge to the poly unit will originate in a recovery-stabilization unit which is being installed as a part of the large cracking installation. The wet gases from the cracking units and the raw pressure distillate from the cracking stills are the source of this material. The charge to the polymer unit will consist of a liquefied product containing methane and other hydrocarbons including butane.

The purified polymer charge gases, which are the fresh feed, are condensed with the recycle fractions. The composite liquefied charge is preheated by heat exchange and passes to the pyrolysis coil where saturated components are partially cracked to unsaturates and the mixture brought to polymerization conditions. Polymerization proceeds in the reaction coil, under controlled temperature and is terminated at the outlet



Flow chart of plant for producing aromatics from natural gas hydrocarbons.

by quenching. Reaction products pass to the fractionating tower system for separation.

Recycle constituents are recovered in the recovery-stabilization unit. The unstable polymer distillate is fractionated in a separate tower. The polymer gas oil is sent back to a regular cracking unit for further processing.

The polymer distillate produced is stabilized to ten pounds Reid vapor pressure and shows an end point not exceeding 380 deg. F.

This plant will produce over 600 bbl. of polymer gasoline per day with the Reid vapor pressure not exceeding 10 lbs. per sq. in. and with an octane rating of 80 C. F. R. M. (neat). The by-products from this plant will be gas with a B. T. U. value in excess of 1000 B.T.U.'s per cu. ft. and polymer gas oil of 6-9 A.P.I. gravity.

The polymer distillate will be clay treated and will be ready after this treatment for blending with refinery gasoline to be marketed.

Alco Products have designed and installed a commercial polymerization plant for the production of aromatic distillate from still gases at a refinery in Ohio. This plant has been designed with the idea of varying the operation to produce a number of aromatic compounds from varying charging stocks.

It will be noted from the above description of the operation that the maximum in flexibility has been incorporated into this plant. This plant serves as a development unit for further experiments on polymerization work. In the past, most concerns have been prone to work with laboratory apparatus and at most, with an enlarged version of laboratory equipment in order to obtain data on new types of operations. The construction of a full-sized commercial polymerization unit for development purposes is regarded as a step forward in the art. Past experience has indicated that equipment many times smaller than a commercial unit does not give reliable data as to certain very important operating characteristics of such plants. It is also hard to rely upon data from very small units for the detail design of commercial plants. It is unfortunate that more pure physical-chemical data are not available in the literature so that plant design can be simplified. The production of aromatics from petroleum gases is so new it is quite probable that most refiners will have installed commercial polymerization units before any great amount of basic data becomes available for the industry. This phase of polymerization, namely, the production of aromatics from petroleum gases and from liquid petroleum, is intimately tied up with the present wide-spread interest in the use of aromatics for internal combustion engine fuel. Here again the industry is hampered by a lack of operating data on aromatic blends for aviation use. Since it has been found recently that engine and operating characteristics influence very greatly the degree of success which aromatic blends may have, it is highly important that not only the simple aromatics, benzol, toluol, and xylol, be produced in commercial quantities, but also to consider that the broad, general term, aromatic blends, may include certain alkylated compounds formed by the addition of an unsaturate (olefin) with a saturate or possibly with a six-sided ring compound. The installation of the Toledo plant was made for these purposes, i.e., new hydrocarbon compounds will be synthesized by the aid of polymerization so that full scale engine tests can be made of these materials and their blends. This plant will also produce mixtures of aromatics and compounds which may be designated as unsaturates which will be used in hydrogenation experiments leading to the development of high octane aviation fuels.

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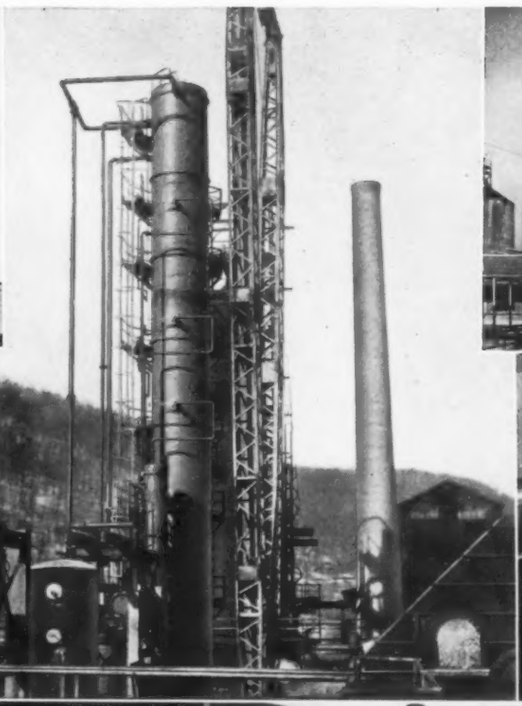
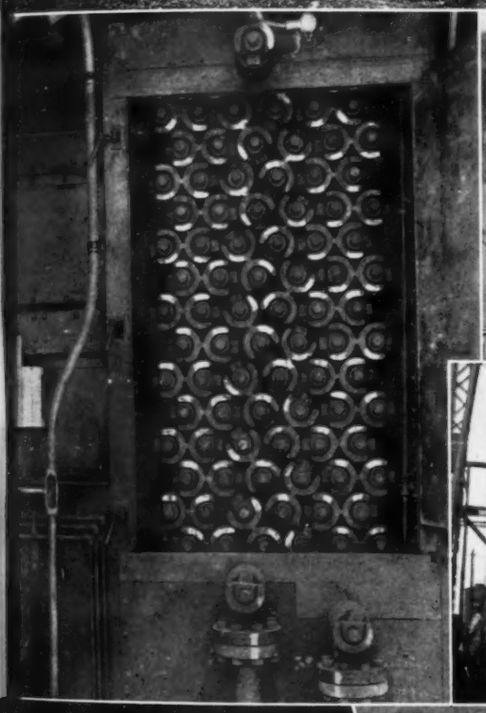
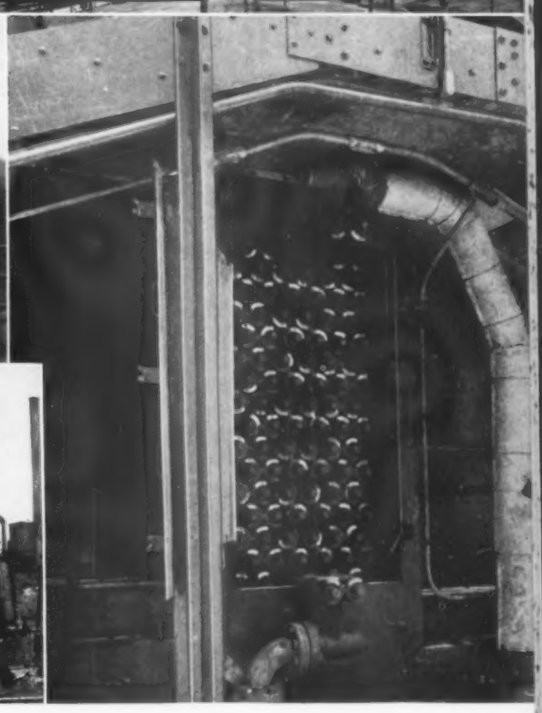
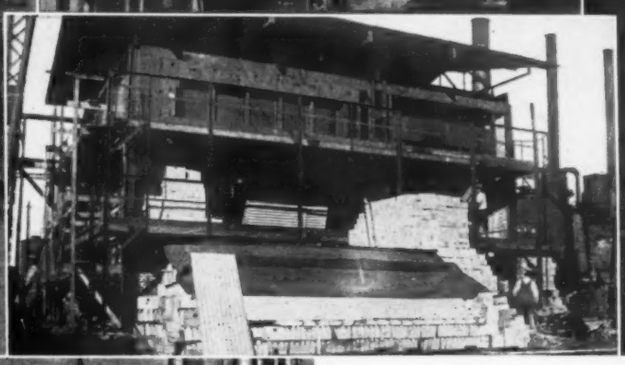








The experience and diligence of Sivyer that produce and maintain Sivyer Safety contribute to the safe and economical operation of Alco installations described elsewhere in this issue.

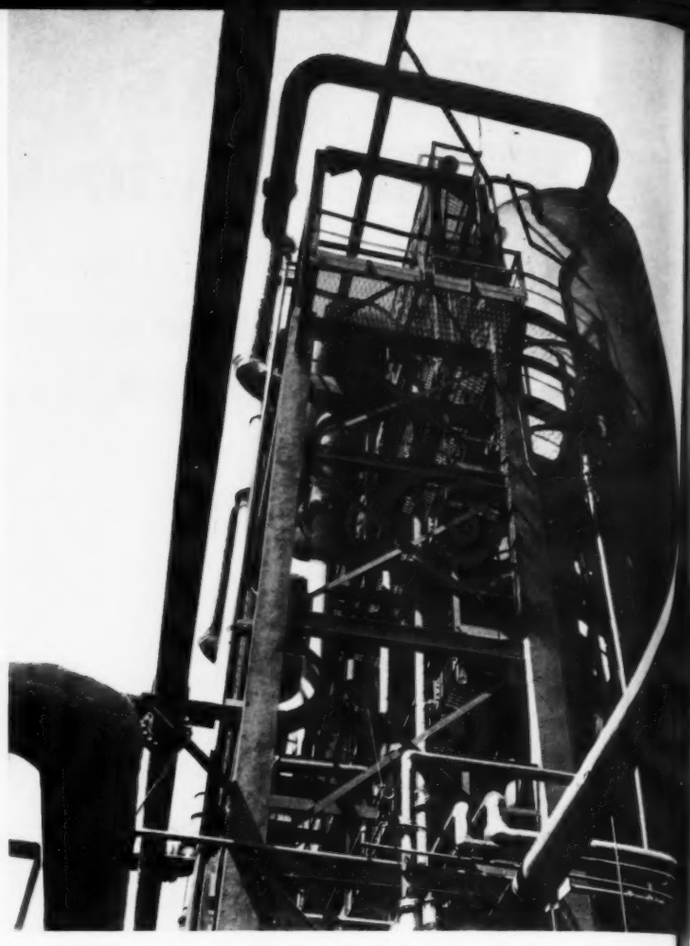
SIVYER STEEL CASTING COMPANY

Milwaukee, Wisconsin

ECONOMIES in OPERATION

Result from Integration of Cracking and Polymerization Units

Distillation, Cracking of Gas Oil and Cracking of Reduced Crude Followed by Polymerization in Integrated Units of a Complete Refinery Offers a Practical System Being Adopted by Many Oil Companies.



Integration of cracking unit and polymerization plant plays a major part in simplifying design and operation.

ILLUSTRATING the pronounced change which has taken place in the cracking art during the past few years is a modern cracking and polymerization plant recently designed by Alco Products.

The art of producing maximum yields of high octane gasoline from various grades of crude oil has been extensively explored and developed during the past few years. The same may be said of the art of producing cracked gasoline from both the liquid phase and the vapor phase cracking systems. In order to achieve the first and major goal, two main systems have been developed. They consist of: (1) distillation, reforming of naphtha, cracking of gas oil and cracking of reduced crude and (2) distillation, cracking of gas oil and cracking of reduced crude followed by polymerization of refinery gas. The process herein described is representative of the second system.

Alco Products, Inc., has been one of the first to realize the importance of combining the polymerization plant with the cracking unit, utilizing a common fractionating system, gas recovery system, and treating plant. The integration of these units not only effects major economies in design, and simplified operation, but gives maximum yields of finished gasoline with low capital investment and minimum operating cost.

An oil company pioneer in the development of polymerization, after exhaustive research in the field of catalysts, high and low pressure polymerization, selected the relatively low pressure thermal polymerization process, using independent pyrolysis and reaction coils, as the most desirable method regardless of capital investment. Several pilot and commercial plants were installed which fully substantiate this research work. Subsequent development by the oil company in combination with Alco Products, Inc. led to several major installations.

These plants conclusively demonstrate that the inclusion of a simplified and efficient polymerization process, with a very low additional capital investment, gives the maximum yield of gasoline from any crude charging stock regardless of varying operating conditions.

The maximum yield of gasoline obtainable from any crude containing a high percentage of asphalt is achieved by the use of successive cracking stages to give carefully selected charging and recycle stocks having the most advantageous hydrogen-carbon ratio. The once-through viscosity breaking operation reduces the asphalt to low viscosity fuel oil with the production of light and heavy gas oil and a minimum percentage of cracked gasoline. Each of these products are then thermally decomposed under the optimum temperature and pressure conditions in the light and heavy gas oil cracking coils.

In order to obtain a maximum octane, there is produced a relatively high percentage of gas. A cracking unit not equipped with polymerization facilities is at a disadvantage in this respect since high octane is associated with high gas loss in cracking. By charging this gas to a polymerization unit a blending stock, very high in octane blending quality, is obtained which not only brings up the yield of cracked gasoline but also makes it possible to raise the overall octane value of the finished gasoline.

OPERATION

Referring to the attached diagrammatic flow chart Figure IV-1 a typical installation operates as follows:

The fresh crude is taken from storage and pumped serially through circulating reflux and gas oil side stream exchangers of the topping stage and circulating and exchangers of the cracking stage. The preheated charge is then introduced into a settling drum where any salt water is withdrawn under pressure. The dehydrated crude leaving the settling drum flows through an additional exchanger on the cracking unit, thence through a crude furnace with an outlet temperature sufficient to effect the desired degree of vaporization, and then introduced into the flash zone of the crude fractionating tower.

In the crude fractionating tower the

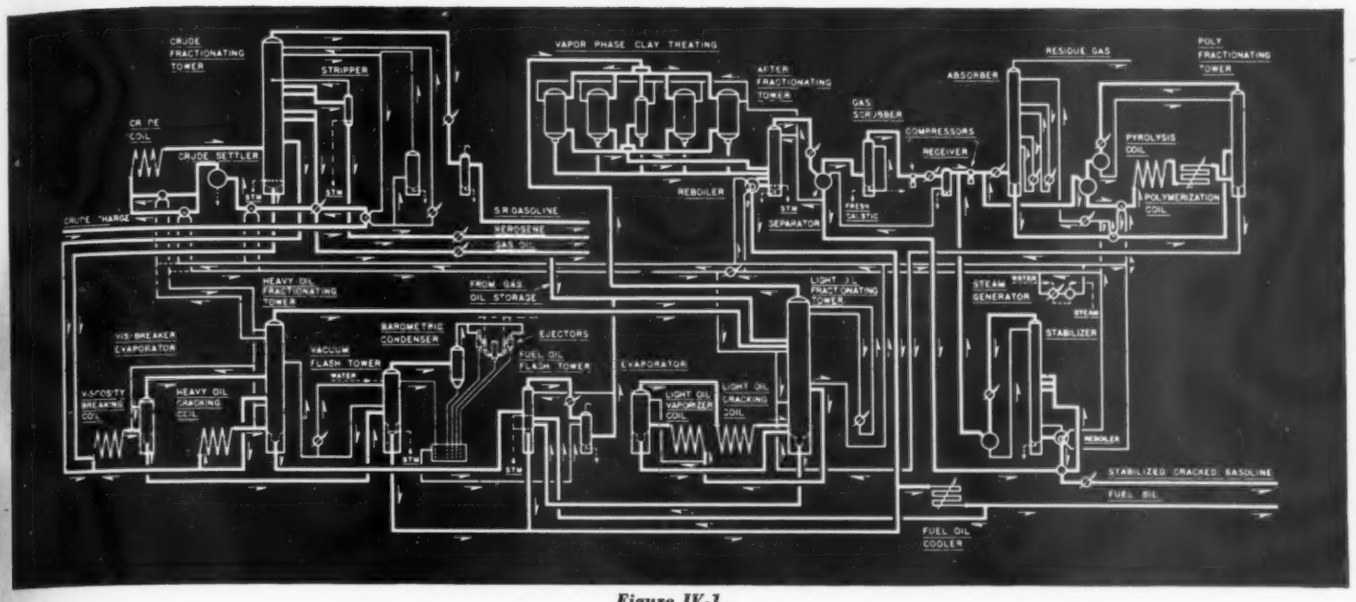


Figure IV-1.

ascending vapors are contacted by reflux, maintaining equilibrium conditions on each bubble tray. The overhead from this tower, consisting of gasoline vapors and steam flows to a vapor condenser where substantially complete condensation is effected. The condensate flows to a water separator where the condensed steam is removed and the net yield of straight run gasoline then flows to an intermediate gasoline storage tank. The endpoint of the overhead gasoline is controlled by pumping a liquid reflux through a heat exchanger and cooler, back to the top tray of the fractionating tower.

A side stream of kerosene is removed from a selected tray in the fractionating tower and flows to an independent external stripping section where the desired flash specifications are maintained. The kerosene leaving the base of the stripping tower flows through a final cooler to storage.

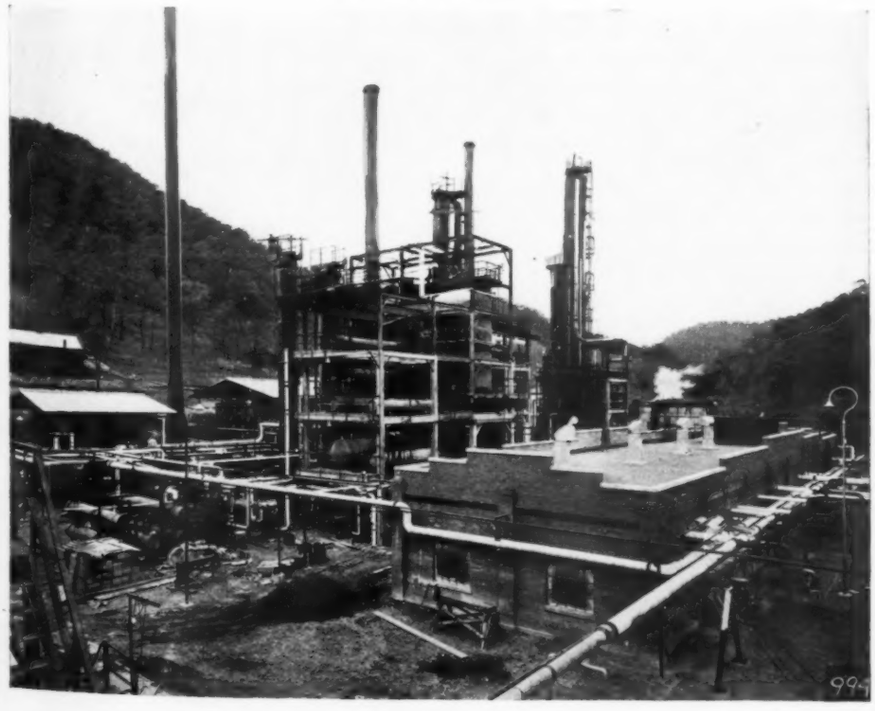
A liquid side stream of gas oil is removed directly from the fractionating tower and flows, by gravity, through an exchanger and through a final cooler to storage.

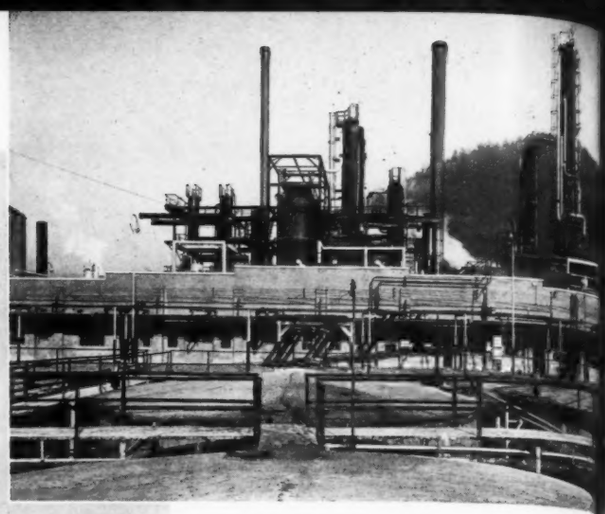
To give flexibility, a side stream of heavy gas oil is removed from the crude fractionating tower and may be introduced into the upper section of heavy oil fractionating tower of the cracking unit. Bottoms from the crude fractionating tower are pumped hot through the viscosity breaking furnace where the desired degree of viscosity breaking is effected under optimum temperature and pressure conditions, and is then introduced into the visbreaker evaporator. The vapors from the visbreaker evaporator are introduced into the heavy oil fractionator, above the pan. The bottoms from the evaporator are introduced into a vacuum flash tower where the heavy cracking stock is removed and the bottoms then flow through the fuel oil cooler to storage.

Bottoms from the heavy oil fractionating tower flow to the upper section of the fuel oil flash tower where the fuel oil is stripped to final specifications and pumped through the fuel oil cooler to storage. Overhead leaving the fuel oil flash tower flows to a vapor condenser where essentially complete condensation is effected and the condensate introduced into a distillate accumulator where the condensed steam is then removed. Oil condensate from the accumulator is introduced into the light oil fractionating tower as recycle stock.

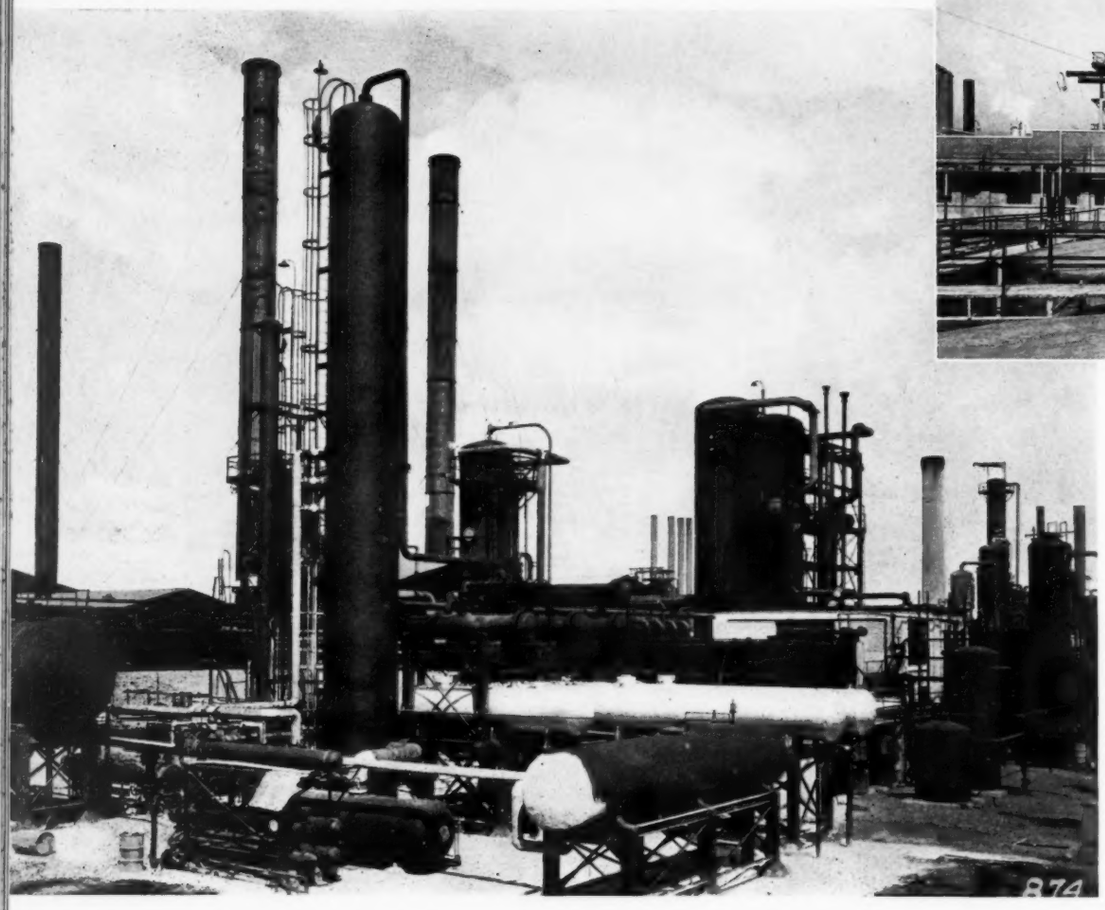
Overhead products (gas, gasoline, and gas oil), leaving the heavy oil fractionating tower are introduced into the light oil fractionating tower where the proper separation between overhead gasoline and cycle stock is accomplished. The endpoint of this material is controlled by reflux circulation. A clean, selected gas oil cracking stock is withdrawn from the reservoir section of the light oil fractinating tower and pumped through the light oil preheating coil and then introduced into an

Long and careful research precedes the commercial application of new cracking processes.



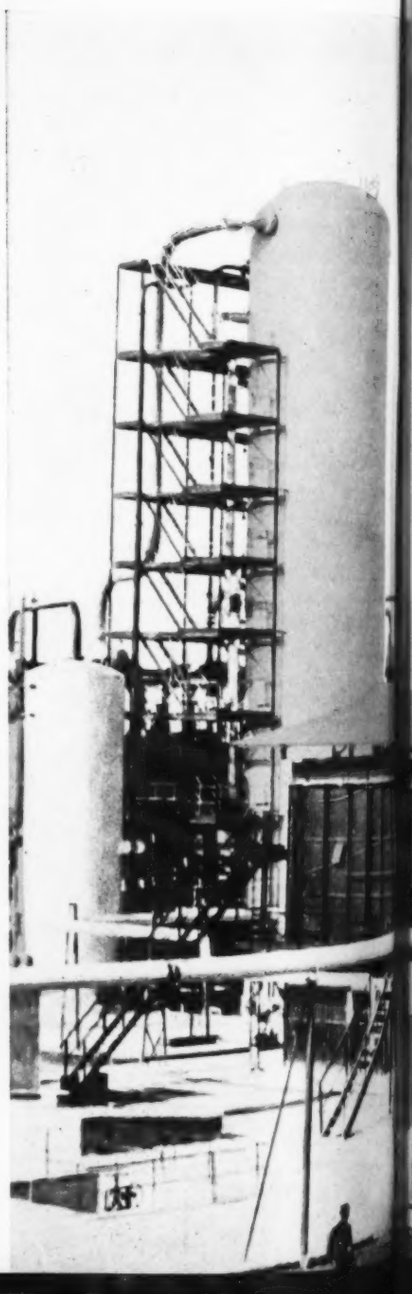


One of the most modern plants in America recently completed by Alco Products.



A new refinery which turns out premier-grade products for the southern state.

A new unit recently added to one of the world's largest refineries.



evaporator where true separation of liquid and vapors is effected. The bottoms leaving the evaporator are re-introduced into the light oil fractionating tower. The overhead leaving the evaporator flows through the vapor phase cracking furnace where the desired degree of thermal decomposition is effected and the entire charge is introduced into the base of the light oil fractionating tower where separation of fuel is accomplished. The bottoms leaving the light oil fractionating tower are introduced into the lower section of the fuel oil flash tower where the refractory fuel may be brought to the desired initial boiling point specifications before being discharged through the final cooler to storage. The overhead vapors from both sections of the fuel oil flash tower flow through the overhead condenser to the accumulator, as previously described.

The overhead from the light oil fractionating tower, consisting of cracked gasoline, polymerized gasoline, and noncondensable gas, flow to a Gray vapor phase treating unit which consists essentially of four clay towers. These towers are so manifolded that all four units may be operated in parallel, or two towers operated in series parallel. Treated vapors leaving the clay chambers flow to an after-fractionating tower from which the overhead gasoline vapors may be regulated to endpoint specifications by means of reflux control. Condensed polymers from the clay towers flow to the fuel oil cooler and to storage.

The overhead consisting of clay treated low endpoint distillate and fixed gas, flow through a vapor condenser and thence to a combination separator and reflux accumulator where separation between the cracked gas and liquid condensate is effected. The gasoline condensate from the accumulator tank is pumped through the stabilizer exchanger and the preheated charge is introduced into the stabilizer tower. The bottoms from the stabilizer, consisting of stabilized gasoline, are discharged through the bottoms exchanger and final cooler and introduced into an intermediate gasoline storage tank with the straight run gasoline described.

The overhead leaving the stabilizer flows through a vapor condenser to a reflux accumulator tank, giving sufficient condensate to provide reflux for the stabilizer tower. The gas leaving the reflux accumulator flows through a vapor condenser and is introduced into the suction of the second stage gas compressor delivering to the absorber.

The gas from the Gray after fractionator

accumulator passes through a gas scrubber where hydrogen sulfide is removed by caustic solution and thence passes to the first stage compressor. After separating any liquid in the accumulator the gas may be delivered to a gas receiver and from the receiver to the suction side of the second stage compressor.

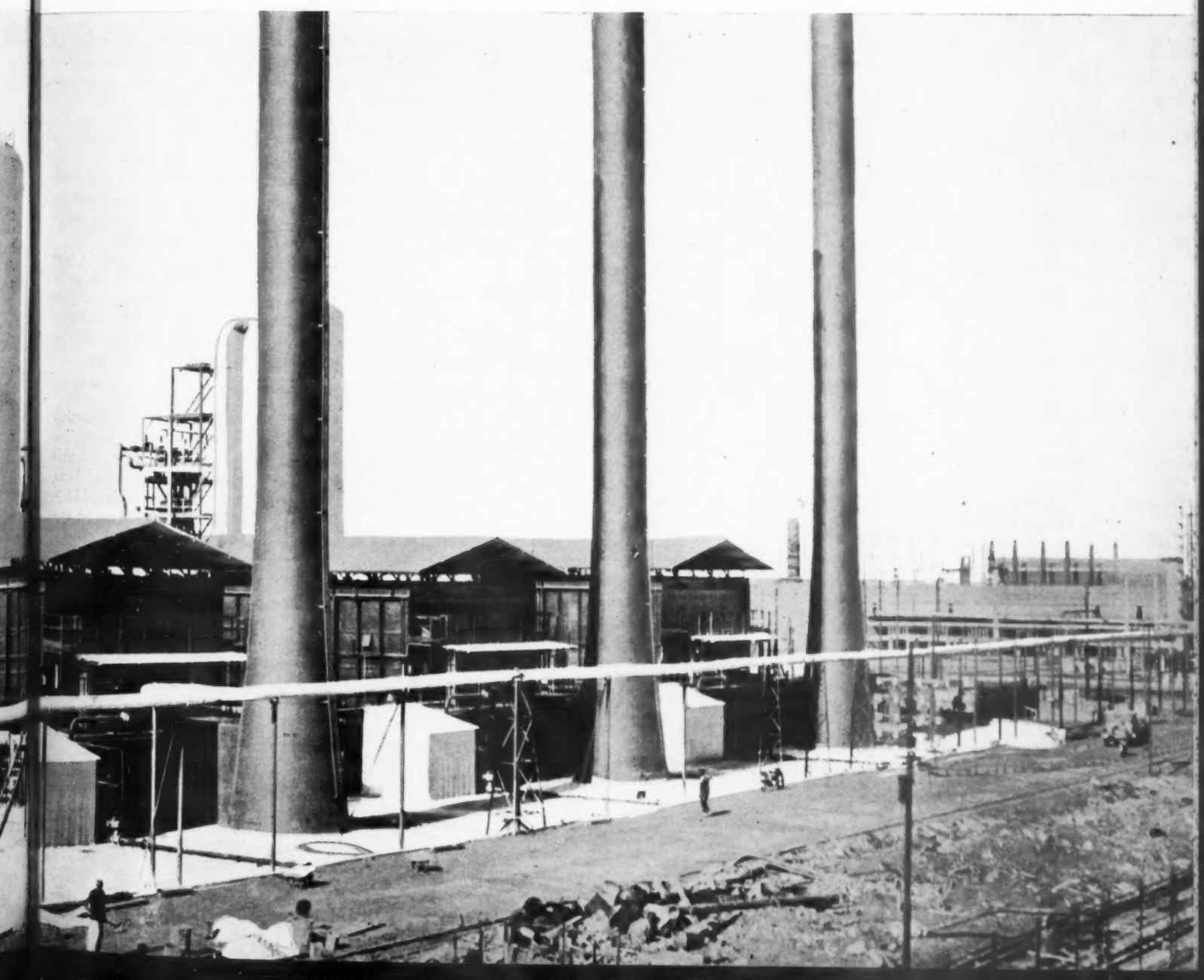
Rich oil from the absorber is charged through the heat exchanger to the poly fractionator and overhead gases and vapors from the fractionator are partially condensed and the condensate used as reflux. The vapors then pass through an after condenser and the mixture enters the poly feed tank. Gases are vented to the absorber and the condensate becomes the poly feed. Lean gas from the absorber is sent to the refinery fuel system. The condensate from the polymer feed exchangers, thence through the heating surface of the polymerization furnace where the temperature is regulated to effect a mild degree of thermal decomposition and raise the products to the desired reaction temperatures. After leaving the furnace, the high temperature vapors flow through the polymerization plant reaction coil and are introduced into the polymerization plant fractionator where the proper separation between polymerized gasoline and cycle stock is effected. The stripped rich oil containing the polymerized gasoline leaving the polymerization plant fractionator is introduced in the outlet of the light oil cracking coil as quench.

In order to utilize the excess heat from the entire cracking operation efficiently a side stream of gas oil (quench oil) is removed from the accumulator section of the light oil fractionating tower and used for preheating the fresh crude to the topping unit, reboiling the stabilizer tower bottoms, preheating the polymerization furnace and the remaining excess heat used for steam generation to supplement the refinery steam generating system.

A portion of this cooled quench oil may be utilized as lean oil for the absorber tower, as intermediate reflux for the light oil fractionating tower, and as quench oil at the outlet of the heavy oil and light oil vapor phase cracking coils. Any excess of cold quench oil is introduced into the light oil fractionating tower as intermediate reflux. The heavy oil tower is provided with a similar independent circulating system, withdrawing oil from the second tray and returning the excess to the top tray as reflux.

In order that the finished gasoline may meet doctor specifications, the stabilized, treated, endpoint cracked and polymerized gasoline is blended with the straight run gasoline in an intermediate storage tank, as previously described, and charged to the doctor treating plant.

A Louisiana oil company operates a refinery, designed and built by Alco Products, which holds considerable interest for the modern refiner. Probably nowhere else is to be found a plant which is comparable in the type of equipment used and the product produced from Mid-Continent type of crude oil. This plant is a combination Gyro vapor



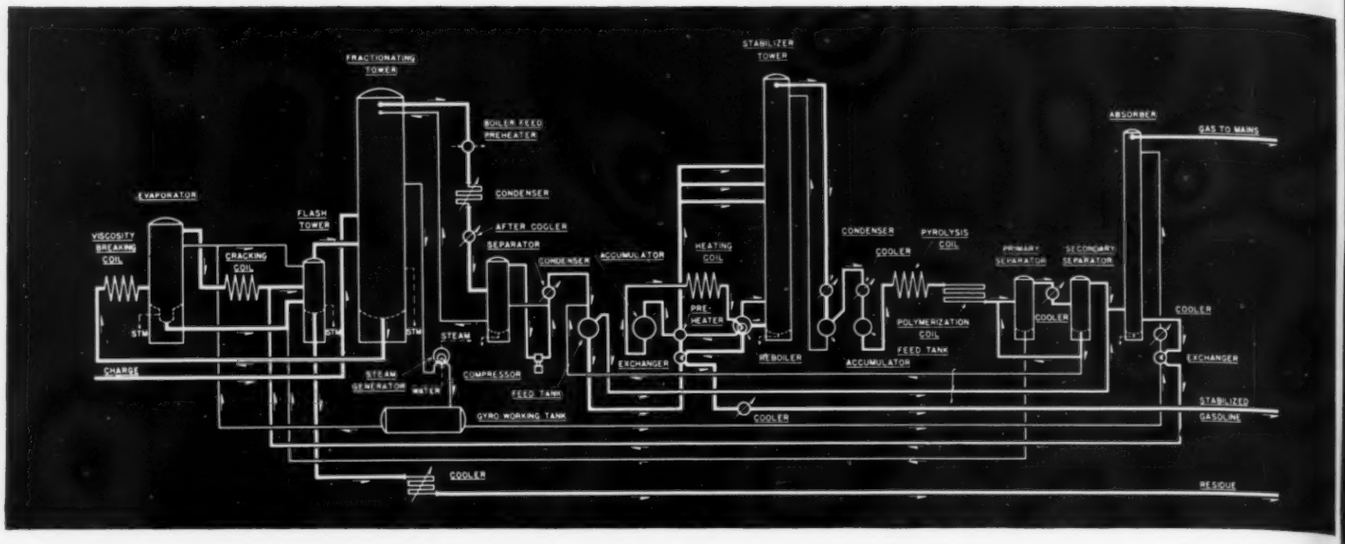


Figure IV-2.

phase cracking system with the Pure Oil thermal polymerization process to operate on the Gyro gases.

Referring to the accompanying flow diagram, Figure IV-2, the operation of the installation is substantially as follows:

The fresh feed, normally East Texas crude oil, is taken from storage and pumped through heat exchanger and thence to the main Gyro fractionating tower above the vapor inlet. This feed stock is preheated by direct heat interchange with the rising vapors and the heavier portions of the feed combine with the liquid in the base of the tower. This liquid constitutes the fresh charge and recycle stock for the Gyro converter. A centrifugal hot oil pump continuously pumps the bottoms from the Gyro tower through the viscosity breaker section of the converter where the viscosity of the feed stock and recycle is lowered by incipient cracking which permits a larger percentage of this oil to be vaporized than would otherwise be possible. The entire charge is then conducted to the evaporator where separation between the oil and vapor takes place. The residue from the bottom of the evaporator, consisting of the heavy portions of the viscosity broken reduced crude and recycle are discharged by pressure into a fuel oil stripping tower, operating at a pressure lower than that maintained in the evaporator. The fuel oil is stripped to specifications. Overhead vapors are introduced into the main fractionating tower where the heavy ends are condensed and combined with the recycle stock.

Overhead vapors leaving the evaporator pass through the cracking section of the converter where thermal decomposition of the oil vapors takes place. Hot vapors are introduced into an arrestor where their temperature is quickly reduced by an injection of light distillate. The temperature reduction effected, arrests cracking and reduces the temperature to a level satisfactory for discharge to the flash tower where the heavier ends are removed by condensation. The vapors then enter the bubble type fractionating tower where the desired separation of the various products is accomplished. The Gyro distillate passes overhead from the fractionating tower and through vapor condensers to the gas separator where the wet gas is separated from the gasoline.

A sidestream is withdrawn from the fractionating tower and is used as quenching oil to be pumped to the arrestor on the Gyro transfer line. The wet gas leaves the separator and is compressed in order to remove the gasoline constituents.

POLY PLANT

The process in use is known as the high pressure low-temperature thermal polymerization process, to distinguish it from the low-pressure-high temperature process, and is as follows:

The charge is known as stabilizer overhead. This liquid under 500-800 lb. pressure is charged to the poly plant heater where it is heated to 900-1,000 deg. F. The heated gases and vapors are then withdrawn to a reaction coil, which is air cooled and located out of the heating zone. The exothermic heat of reaction is so great that cooling has to be resorted to in order that the polymerization reaction will not progress too far and form large amounts of tar and coke. At the completion of the polymerization reaction, the product is quickly chilled and conducted to the flash tower. Poly gasoline is crudely separated from fuel oil and vapors are sent to the main Gyro fractionating tower. The polymer gasoline is in this way blended with the Gyro gasoline vapors and the mixture of gasolines is taken overhead from the tower.

Gyro and polymer distillate mixture is pumped through heat exchanger and thence through a heating coil located in the furnace. The distillate is held under a pressure of 600-1,000 lb. which keep it in substantially liquid phase during its passage through the system. The distillate is heated to 500-600 deg. F. and flows through a bed of Fuller's earth held in a conventional reaction chamber. A screen inserted in one end of the clay chamber prevents the Fuller's earth from being carried out with the distillate, and the latter then returns to a reheating coil, located in the convection section of the heater and is raised in temperature 25 deg. F. which is sufficient to enable the rectification operation possible without a reboiler on the tower.

The gasoline vapors separated in the rerun fractionating tower are taken overhead and the heavy polymer, formed in the clay treating operation, is withdrawn and returned to the Gyro cracking unit for cracking into more gasoline.

PRODUCTS

The finished gasoline shows an induction period of four hours plus. The gasoline produced ranged from 17-22 color and this was obtained when 30,000 bbl. had been passed through a ton of clay. A color of 25+ could be obtained by cutting down on the yield per ton of clay.

The octane rating of the finished gasoline is practically the same as the same endpoint material cut from the distillate— this means practically no octane depreciation has taken place in the clay treating operation.

In California, Alco Products designed and built a two-stage visbreaking unit to process 14,500 bbl. per day of heavy Ventura residuum and operate in conjunction with complete independence of operation between the two units is provided.

Description of the flow is as follows: The

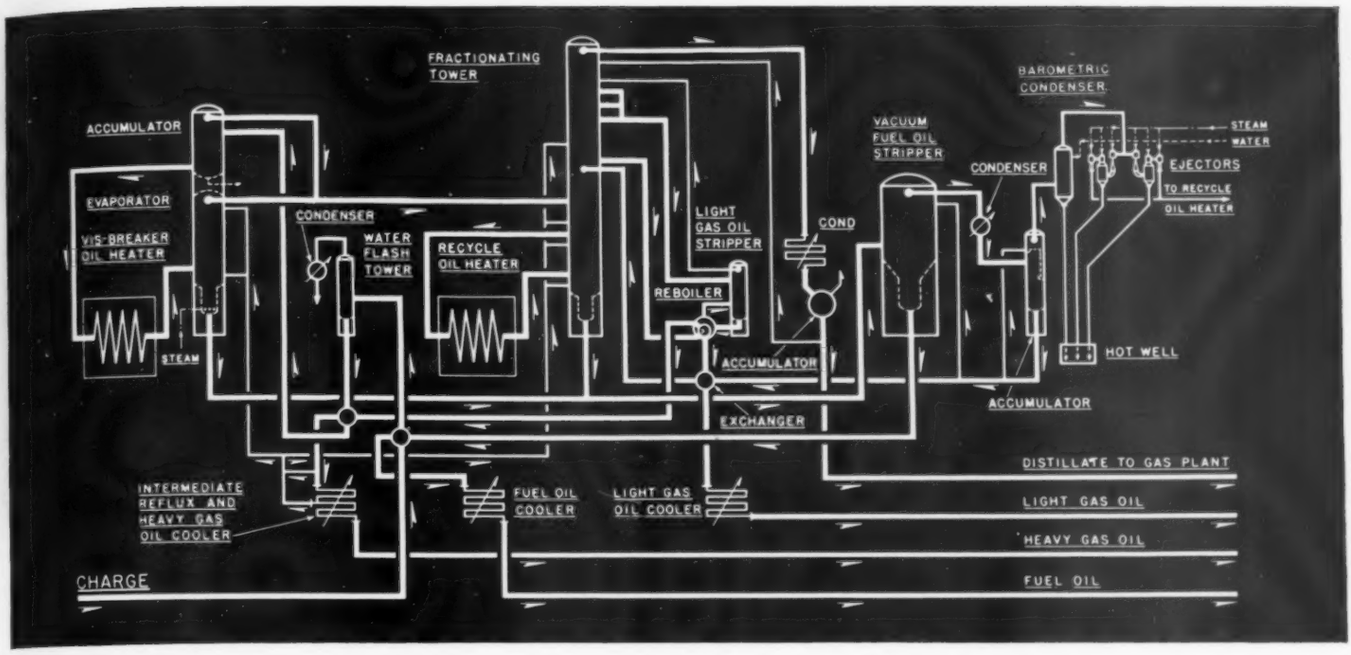


Figure IV-3.

heavy crude is pumped through heat exchangers to the water flash tower. A new pump takes suction from this tower and the dehydrated crude discharges through new circulating oil exchangers to the accumulator. If desired, when operating on Ventura residuum, the water flash tower may be by-passed and the new charge pump take suction from intermediate storage.

A hot charge pump takes suction from the accumulator and discharges through the once-through visbreaking coil into a separate evaporator. The vapors from this tower pass to the fractionator and the bottoms to the vacuum flash tower. A separate evaporator has been provided for this operation so that by suitable tests on the fuel oil and vapors, full advantage can be taken of the flexibility of this furnace for the production of various yields of light products.

In the vacuum flash tower, the bottoms are reduced to pitch and then combined with the fuel stripper bottoms from the cracking unit before entering the residuum to charge exchangers. The overhead from the vacuum flash tower is condensed and returned to the fractionator tower as cycle stock.

The fractionator tower consists of two sections, a lower or recycle evaporator section, and the upper fractionator section. A pan for the accumulation of heavy recycle stock is placed between these sections. The vapors from the two evaporators are fractionated in the upper section, and the heavy recycle is condensed. A hot oil pump charges this heavy cycle to a recycle furnace and the cracked products are returned to the lower, or evaporator section. The bottoms are flashed in the existing cracking unit fuel stripper and combined with the fuel from the other units. The overhead from the fuel stripper is returned to the fractionator of the cracking unit.

In the upper section of the fractionator, light and heavy gas oil streams are removed as side streams and the gas and gasoline pass overhead. The heavy gas oil is used as circulating oil to preheat the charge and is returned to the tower as intermediate reflux. A portion may be removed from the system and cooled if desired. The light gas oil is stripped and passed through exchanger and cooler to storage. This forms the charge to the existing cracking unit.

Fractionation of the overhead products is obtained by the return of reflux to the top of the fractionator tower. The final separation between wet gas and raw pressure distillate is made at the stabilization unit.

The operation of the existing cracking unit is generally similar to its former operation, except that piping changes were made to incorporate light oil fluxing and eliminate former difficulties with coking, experienced when operating on a light gas oil charging stock. Removable trays were installed in the evaporator to insure a clean charging stock to the furnace. This unit is operated at low cycle ratios and for a light fuel oil for blending to produce a combined fuel oil of the proper viscosity specifications.

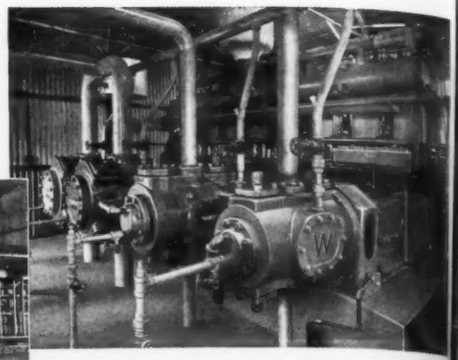
High recovery of butane and heavier fractions in the wet gas from the visbreaking operation is effected by absorption. A high pressure absorber will be included to treat the wet gas from the cracking unit.

In addition to the wet gases, the charge to the new stabilization unit will consist of raw pressure distillate produced by the visbreaking unit plus stable pressure distillate. A heavy stable gasoline is made as a bottom product from the primary fractionator and represents approximately 65 percent of the total stabilized gasoline. Butane and heavier constituents made as a bottom product from the secondary fractionator, form the light stable gasoline and represent approximately 35 percent of the total. The raw pressure distillate from the cracking unit will be processed in existing stabilizing equipment.

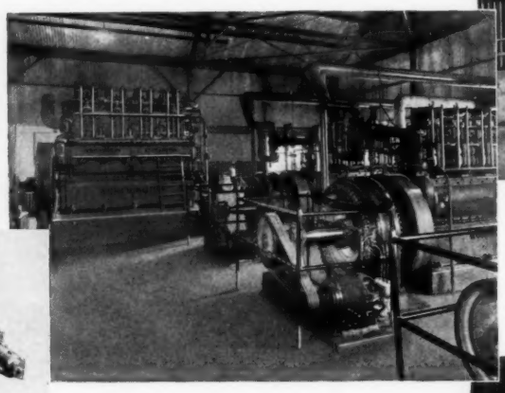
Another unit designed to operate under Gasoline Products license incorporates all of the latest features of high and low pressure tower operation for the greatest economy in fuel consumption, yields and time on stream.

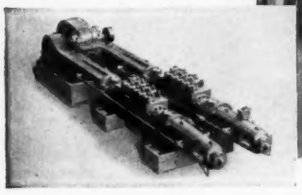
Referring to diagrammatic flow sheet Figure IV-3, the hot reduced crude is charged directly into the heavy oil fractionator tower which will operate at reduced pressure. Ample heat has been provided in this tower to distill light gas oil overhead and preheat the incoming reduced crude. Normally the cold gas oil cracking stock is charged directly to the flash distillate accumulator, from which it enters the high pressure fractionator tower. The heavy charge accumulates in a pan together with the recycle stock and is charged through the heavy oil cracking coil into the base of the heavy oil tower. The heavy oil coil will be operated under mild conditions at a low crack per pass for the maximum production of light gas oil. The low pressure operation in this tower permits reduction of the fuel oil to the minimum.

The complete installation has been designed to process 1,500 bbl. per day of Mid-Continent crude and 2,000 bbl. per day of blended Pennsylvania crude.



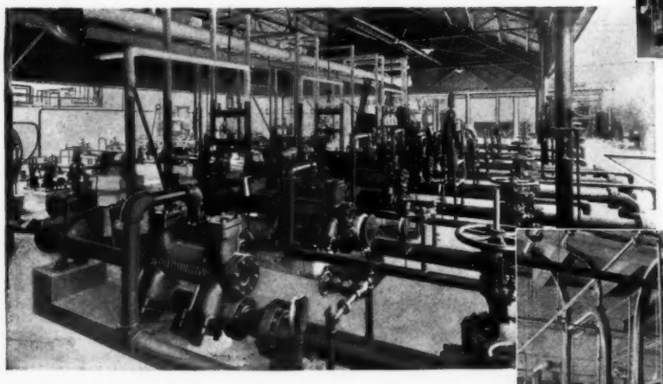
Worthington Gas Engine Generator Units and, in background, Worthington Diesel Engine direct-connected through fire wall to Worthington Horizontal Duplex Hot Oil Pump



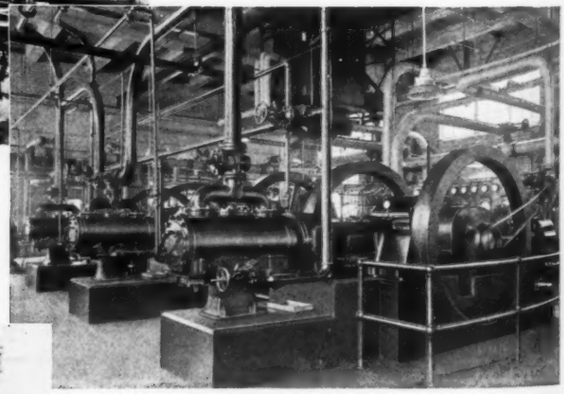


Worthington Angle Gas Engine Compressor in refinery service

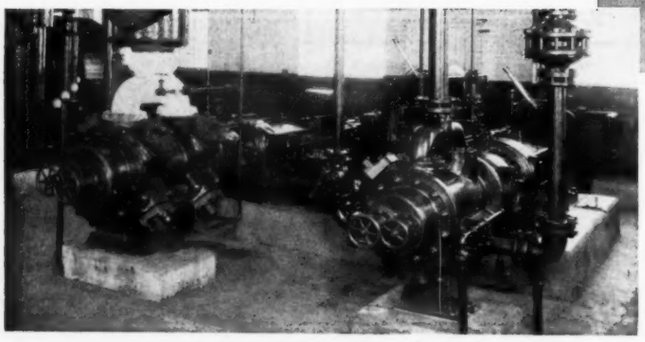
Worthington Horizontal Single Direct-Acting HiVol Pumps in a mid-continent refinery



A battery of Worthington Centrifugal Pumps in refinery service



Carbondale Horizontal Two-stage Ammonia Compressor, with capacity control

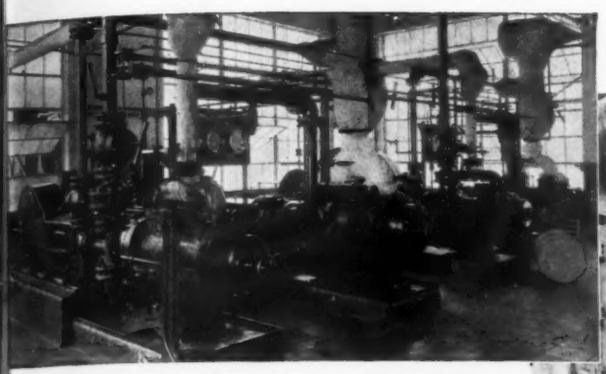


Three Worthington Horizontal Single Gas Compressors, steam-driven, in a large refinery

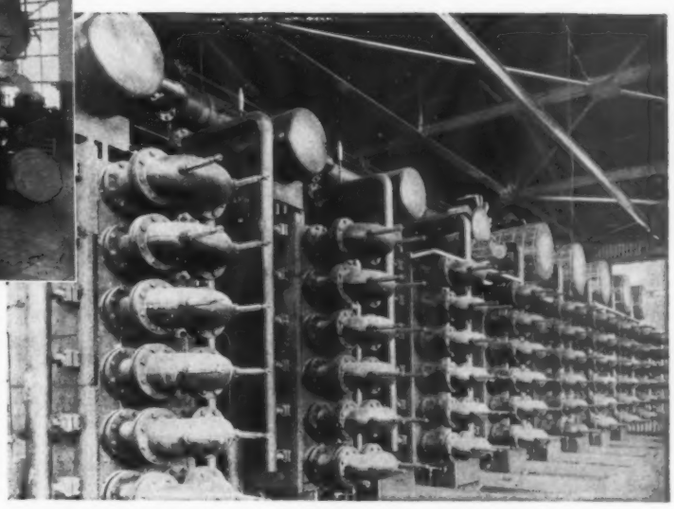
IC7-32

WORTHING

CARBONDALE



Two Carbondale Horizontal Two-stage Ammonia Compressors, with double-seal stuffing boxes and capacity controls, motor-driven



Carbondale Type Chilling Machines for ammonia direct-expansion operation

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●

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IGTON-CARBONDALE

DISTILLATION PROGRESSES from Fractionation to Super-Fractionation

Super-Fractionation of Straight Run Gasoline Will Make 87 O.N. Motor Fuel Available from Great Variety of Low Gasoline Content Crudes.

THE oil industry has a widespread interest in the production of new products from petroleum—high octane gasolines, solvents, chemicals, etc., and almost every new endeavor of the refiner is accompanied by the main problem—superfractionation. He must either make closer separations between hydrocarbon groups, or he must use this tool to increase the yield of the desirable products already being manufactured.

Alco Products has installed units which are prototypes of more to follow in the field of superfractionation. Illustrative of one branch of the new and improved art is the plant of which the flow diagram is shown in Figure V-1.

ISOPENTANE

With the increase in octane of aviation fuels, there has come about an ever increasing demand for its components among which is isopentane. With an octane value of 94 (C.F.R.M.) and with its physical characteristic of boiling point, this material is very much in demand.

One of the chief sources is natural gas but any other gas or liquid carrying it in appreciable quantities can be used as a source.

The flow diagram Figure V-1 indicates the flow through a plant designed by Alco Products for this purpose.

The charge is pumped through the feed heat exchangers and discharged into the fractionator tower. The gross overhead passes through the reflux condenser where the reflux is liquefied by partial condensation and the net overhead flows to the final condenser. Since a high reflux ratio is required for the proper fractionation, the reflux is condensed at a comparatively high temperature and only the isopentane product requires cooling to nearly water temperature. This procedure effects a large saving in condenser surface.

The feed and reflux are maintained at constant rates of flow by controller-recorders; the end boiling point is controlled by a temperature controller-recorder. This instrument resets the reboiler temperature controller to satisfy the fixed top temperature.

Since the iso-pentane product is totally condensible, a pressure controller actuated by the vapor pressure in the final accumulator would give erratic operation, therefore the pressure of the unit is controlled by regulating the flow of water from the final condenser.

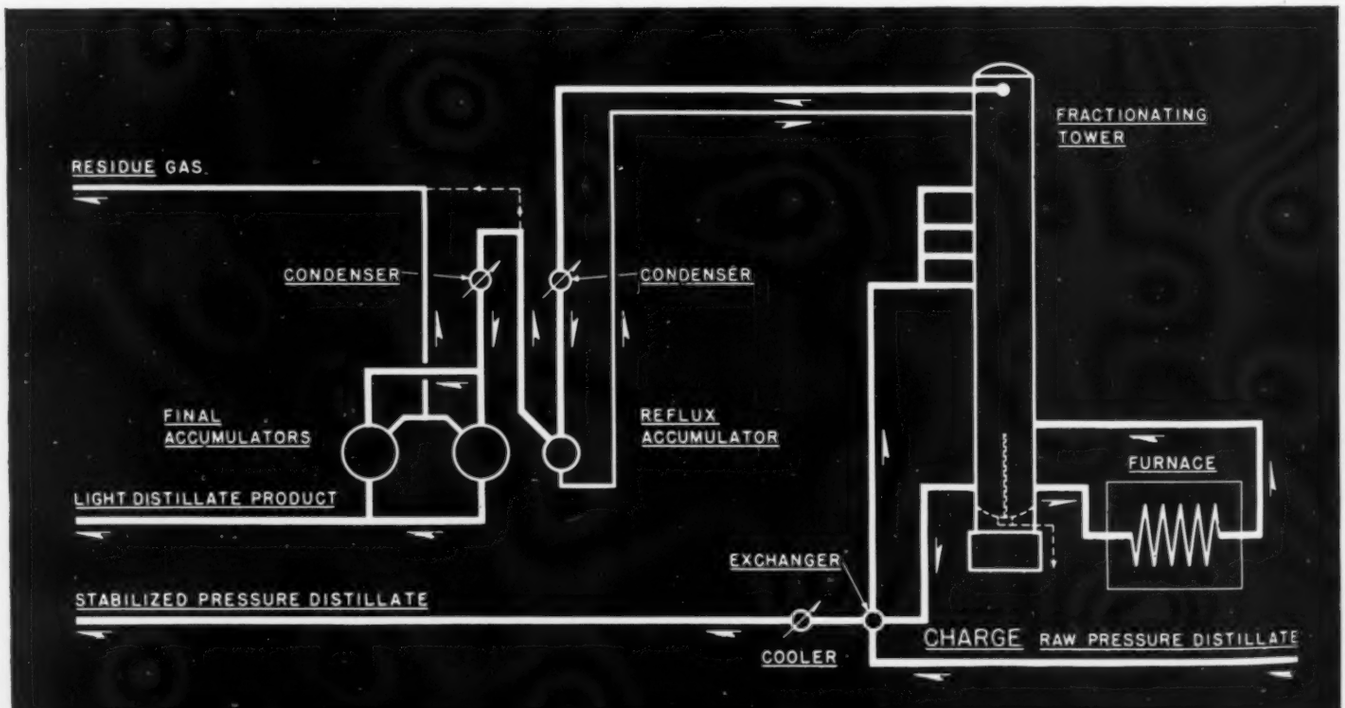
The level in the reflux accumulator is controlled by bypassing a small portion of the vapors around the reflux condenser. This permits full flow of water through the condensers, preventing the tendency to scaling which is probable when the accumulator level is controlled by reducing the water flow through the condenser.

RERUN UNITS

Another important member of the superfraction family is the rerun plant (for solvent production). These plants have for their object, the separation of narrow boiling range from distillates of wide boiling range.

Alco Products designed and built a solvent rerun plant for the separation of solvents with boiling ranges no wider than 60-70 deg. F., from initial to final boiling points. The flow diagram Figure V-2 indicates the flow through the plant.

Figure V-1



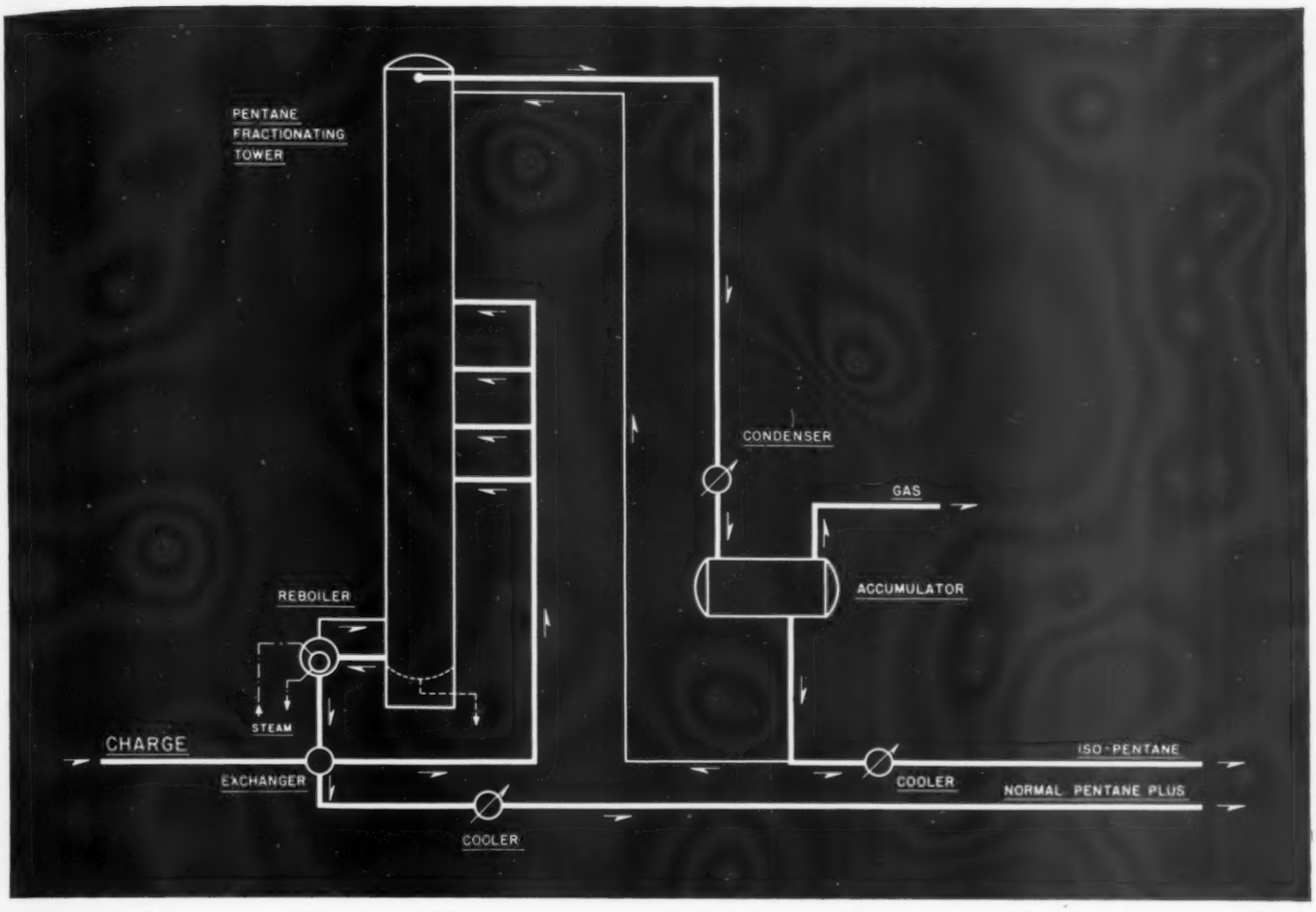


Figure V-2

The tower is capable of operating at pressures up to 25 lb. gauge and has been designed for the continuous removal of overhead light gasoline, one side stream of solvent naphtha and heavy naphtha bottoms. A reboiler located at the base of the tower, in combination with the steam preheater, supplies the desired amount of reboiling to maintain the required reflux ratio for separation of any of the solvents.

The ascending vapors pass upwards through the fractionating trays and are contacted and partially condensed by the down-flowing reflux, maintaining equilibrium conditions at each bubble tray. The overhead from the fractionating tower, consisting of light gasoline vapors, flows to a vapor condenser and the entire condensate is collected in a distillate accumulator. A part of the condensate will be pumped over the top tray of the fractionating tower in order to maintain the desired end-point on the overhead product.

A side stream of solvent naphtha is removed from a selected tray in the fractionating tower and flows to an independent external stripping section, fitted with a closed steam reboiler, where the solvent naphtha is regulated to the desired initial boiling point specifications. From the reboiler the solvent naphtha flows by gravity through a final cooler; thence through the control house to the run-down tank or to storage.

The heavy naphtha is pumped from the reboiler at the base of the tower and after flowing through a final cooler is discharged into a section of the overhead accumulator, where the net yield of overhead and the heavy naphtha bottoms are blended as a single stream. The blended gasoline flows by gravity through the final cooler and thence to storage.

The side stream is regulated from the control room by means of a micrometer control valve, which maintains a uniform temperature in the main fractionating tower at the point of side stream removal.

The general plan arrangement of the entire installation requires a battery limit approximately 45 ft. in width by 35 ft. in depth.

DESIGN

The plant design has been based on the most severe operating condition, which consists of processing charge "A" in a sufficient quantity to recover 3,400 I.G.D. of Solvent No. 3. In order to segregate this product, having a 25 deg. C. boiling point range, from the heavier charge, the fractionating tower, reboilers and condensers have been designed for a 4 : 1 cold reflux ratio.

In order to operate at minimum temperature and pressure conditions and, at the same time, effect complete condensation, the heavy naphtha bottoms have been combined with the light naphtha condensate before flowing through the after cooler to final storage. Although the combining of these products will effect complete condensation of the overhead at lower pressure than would otherwise be possible, complete condensation can only be effected, when recovering certain solvents, by operating at pressures in excess of atmospheric conditions. In view of the nature of the charging stocks and the quality and quantity of the various solvents desired, we have designed the plant to operate at pressures up to 25 lb. gauge, permitting complete condensation for any operating conditions.

Due to the variable quantities and temperatures at which the various products are recovered, it was necessary to design each exchanger for extreme operating conditions, causing a relatively high

capital investment. By the utilization of exhaust steam in the steam heater the fresh charge may be preheated to approximately the same temperature, representing a relatively small surface as compared with the installation of exchangers for each product.

The fractionating tower has been designed with Alco stream-line bubble trays. This type of bubble tray permits the removal of a side stream at any tray inlet seal and has the following advantages:

(1) Elimination of packed joints and leakage between trays.
(2) Accessibility by ready removal of all caps and troughs, eliminating a large number of external manholes.
(3) Uniform patch of liquid flow with minimum frictional reistance, giving practically a uniform hydraulic head for the entire tray.
(4) Long distribution and overflow weirs, giving minimum change in static head for varying operating conditions.

The use of multiple manifolding at the point of introduction of the charge to the fractionating tower, and removal of the side stream from a selected tray, permits of varying the number of trays in each section of the tower in accordance with the desired degree of fractionation and specifications of the particular solvent desired.

PRIMARY DISTILLATION

As stated elsewhere in this article, the refining industry has widely adopted modern pipestill-fractionating distillation units and has discarded the old shell type stills due to their inefficiency. Continuous research and development have steadily improved the efficiency and ease of operation of these new plants which handle as much as 90,000 bbl. of crude oil per day. Here we have had an increase in daily capacity per unit from 1,000 to 3,000 bbl. per day to 90,000 bbl. not to mention the increased efficiency of operation. One of the latest designs is illustrated by a 7,500 bbl. atmospheric distillation unit.

See flow diagram Figure V-3.

The fresh crude charge is pumped serially through the heat exchangers located on the circulating reflux and gas oil streams and part of the heat exchangers on the intermediate reflux stream and is introduced into a salt settler held under sufficient pressure to prevent the vaporization of water.

The crude flows from the settler through the remaining intermediate reflux heat exchangers, bottoms heat exchangers, and through the convection and radiant sections of the furnace. The charge flows in four parallel streams through the economizer section of the convection bank, thence in two parallel streams to the roof of the combustion chamber. The entire charge is then introduced into the flash zone of the fractionating tower at the temperature required to effect the desired degree of vaporization.

The overhead leaving the top of the fractionating tower, consisting of gasoline vapors and process steam, flows to an overhead condenser and cooler, thence to a water separator where the condensed steam is removed. The net yield of gasoline distillate flows by gravity to storage.

Liquid side streams are removed from selected trays in the main fractionating tower and flow to individual external stripping sections where each product is brought to the desired initial boiling point specifications. From the stripping sections the first, third, and fourth side streams flow through independent final coolers to storage. The second side stream flows through a heat exchanger and final cooler to storage. The unvaporized liquid from the base of the tower is pumped to existing No. 4 unit vacuum stage or through heat exchangers and final coolers to storage.

The endpoint of the overhead gasoline is regulated by recirculating liquid from the collecting pan of the fractionating tower through the crude heat exchanger and the final cooler to the top tray of the fractionating tower, utilizing liquid to liquid heat exchange. The quantity recirculated is controlled by tower top temperature.

An intermediate reflux stream is withdrawn from the fractionating tower four trays below the point of gas oil removal and pumped through heat exchangers on the crude charge. The cooled reflux is reintroduced in the tower two trays below the gas oil removal tray. This intermediate reflux stream is maintained at a constant rate of flow by means of a flow controller.

PROCESS DESIGN

For this design the basic principle of single flash distillation, utilizing top and intermediate circulating reflux has been followed.

The use of intermediate reflux permits a reduction of the heat load at the top of the fractionating tower, and gives a high final preheat temperature when the unit is being operated for a low percentage of residue. The heat which would otherwise represent excess reflux in the fractionating tower is thus utilized to reduce the fuel consumption of the plant, and less furnace surface may be installed because of a reduced furnace duty.

The location of heat exchange equipment has been chosen to give the desired preheat with maximum operating stability. The high proportion of heat removed from the top and intermediate reflux insures uniform preheat when withdrawing various percentages of overhead, side stream, and bottoms products.

The furnace is of Alco bare tube design, consisting essentially of radiant and convection sections located in a single setting. A single row of radiant tubes has been used on the floor, side walls and roof of the combustion chamber, giving uniform tube wall temperatures at all sections of each tube, and permitting a closer approach between oil and tube wall temperature than would otherwise be possible.

The oil flow through the heating surface has been designed with four tubes in parallel through the low temperature convection section, and two tubes in parallel through the radiant section. Positive distribution of the crude quantities to each pass may be regulated at the tube still inlet, insuring uniform conditions throughout the entire heating surface. The radiant surface is symmetrical with respect to the combustion chamber with uniform firing and even heat distribution.

Radiant roof tubes of larger cross section than the floor and wall tubes have been provided to permit the maximum vaporization within the furnace, resulting in the minimum furnace outlet temperature.

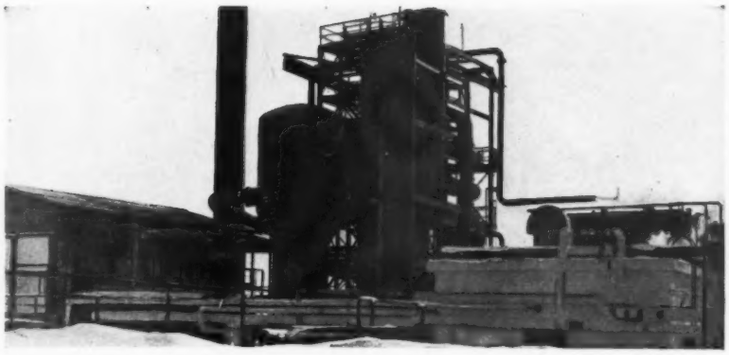
The atmospheric tower has been designed with 36 trays above the inlet in order to insure a high degree of fractionation. Diameter and spacing of trays in the atmospheric tower has been maintained uniform throughout. Twelve fractionating trays have been supplied between the tower inlet and the point of wax distillate removal in order to maintain pressability. Fractionating trays are of Alco streamline design, modified to give a bolted type tray support on tower shell.

The utilization of external stripping section and multi-drawoff connections from selected trays in the fractionating tower permits of varying the number of trays between streams, giving a high degree of flexibility for charging various crudes and regulating the characteristics of each product according to market conditions.

The method of side stream control is accomplished by means of a micrometer type air actuated regulator on the control board, which is adjusted to maintain a constant tower temperature at the point of side stream removal from the fractionating tower. This regulator permits minute adjustment of the rate of flow and the operator may maintain uniform conditions through the entire fractionating zone.

Alco Products designed and built another most interesting crude oil distillation unit to operate with the minimum of expense. See Figure V-4.

The unit charges 16,000 bbl. of crude oil per day.



Modern pipe stills have replaced the old and inefficient shell stills.

The crude is pumped serially through the top reflux, gas oil sidestream, intermediate reflux and fuel oil bottoms heat exchangers, giving a high degree of preheat to the entire charge. Preheated crude flows in four parallel streams through the convection heating surface of the furnace, then in two parallel streams through the floor, wall, and roof tubes of the radiant section. The furnace outlet temperature is controlled to effect the desired degree of vaporization and the entire charge is introduced into the flash zone of the fractionating tower.

In the fractionating tower the ascending vapors are contacted with the down-flowing reflux, maintaining equilibrium conditions on each bubble tray. Overhead from the tower, consisting of process steam and gasoline product vapors to endpoint specifications, flow to a vapor condenser where complete condensation and sub-cooling is effected. This condensate flows to a water separator where the condensed steam is removed. The accumulated naphtha product to endpoint specification is withdrawn continuously and discharged to storage.

The fractionating tower is refluxed by means of circulating liquid reflux. This reflux, hot, is withdrawn several trays down from the top of the tower and is pumped through the crude exchanger, thence to a tubular cooler and back over the top tray of the tower at a temperature and in controlled quantities to effect condensation of the necessary internal reflux required for fractionation below this section.

Sidestreams of refined oil and gas oil are removed from selected trays in the main fractionating tower and flow, by gravity, to independent external stripping sections where each product is stripped with open steam to maintain the desired initial boiling point specifications. The products from each stripping section are pumped through independent final coolers, thence through the control house to storage. A stream is removed from the tower four trays below the point of removal of the gas oil stream and returned two trays below the gas oil stream as intermediate reflux after heat exchange with the crude.

The unvaporized crude flows down over six stripping trays located in the lower section of the fractionating tower and is pumped hot through the bottoms exchangers, thence through the fuel oil cooler to storage.

A steam superheater located in a lower temperature zone of the convection section of the tube still is utilized for superheating the necessary process steam required in the base of the tower and in the stripping sections.

Regulation of each sidestream is operated from the control house to maintain a constant temperature at the point of side stream removal in the fractionating tower.

GENERAL DESIGN

General design of the installation was based on minimum operating costs.

Characteristics of the crude under consideration were such that abnormally high flash temperatures were necessary for the degree of vaporization required; consequently, there is a large amount of heat available in the residual bottoms for preheating the crude. By utilizing heat exchangers on the recirculation reflux, gas oil side stream, intermediate reflux, and residual bottoms, a high preheat are obtained.

The point of intermediate reflux has been selected to meet the following requirements:

1 Highest temperature level heat source.
2 Maximum simplicity in design.

By supplying intermediate reflux below the gas oil the tower diameter required at the top is the same as that required below the gas oil. A tower of uniform cross section with low vapor velocities is thus obtained. Due to the heat exchange balance selected, the reflux ratio in the upper section is the maximum obtainable with the selected preheat.

The tube still is of the Alco bare tube design.

The radiant surface has been designed with a single row of radiant tubes spaced on centers approximately equal to twice the tube diameter, giving uniform peripheral heat intensity. Convection tubes have been placed on relatively close centers, giving high flue gas velocity with a high rate of heat transfer, insuring low exit flue gas temperatures. Heating surface of the radiant section has been symmetrically disposed with respect to the flue gas outlet from the combustion chamber, insuring uniform firing conditions. The dividing of the charge into two parallel streams at the inlet, and the maintaining of a single flow through two parallel radiant zones symmetrically disposed insures optimum control.

The fractionating tower was designed with 28 trays in the fractionating zone, insuring adequate fractionation for the crude operation. Below the tube still inlet six trays were included for reducing the fuel oil bottoms to high flash specifications.

The utilization of external stripping sections on both side streams, with multi-drawoff connections from selected trays in the fractionating tower, permits of regulating the number of trays between each stream.

All bubble trays will be of Alco streamline design, elongated bell cap type, with cast iron caps and troughs.

One of the most flexible primary distillation units so far designed is exemplified by an Alco installation designed to operate efficiently as (1) a vacuum reducing unit, (2) a vacuum distillation unit, or (3) an atmospheric distillation unit. This design provides the maximum in flexibility.

The complete installation is capable of processing 4,500 bbl. per day of 50-55 percent of reduced Iraq crude, and when operating as a vacuum distillation unit produces gas oil, cracking stock, slop oil, and residue. As an alternate, it may be operated as a vacuum reducing unit charging 3,650 bbl. per day of 40-45 percent of reduced Iraq crude and produce gas, gasoline, cracking stock, and asphalt.

OPERATION

When the unit is operated for vacuum reducing, the operation is shown diagrammatically on flow chart Figure V-5.

The charge is taken from storage and passed through a series of heat exchangers entering a furnace in series, passed across the floor tubes, up the floor wall, across the roof and out the near wall, entering a pressure flash tower. Back pressure is held upon the furnace and the pressure released into this tower. Sufficient pressure is held upon the tower to maintain a temperature in the base which will permit flashing of the bottoms to asphalt in the vacuum tower. The overhead in this tower consists of any gas or gasoline formed in the furnace. Facilities are provided for the removal of a sidestream of gas oil which is stripped and returned to the vacuum tower where it is fractionated as desired. This removal of a side-stream permits the stripping of the charge to the vacuum tower to reduce any

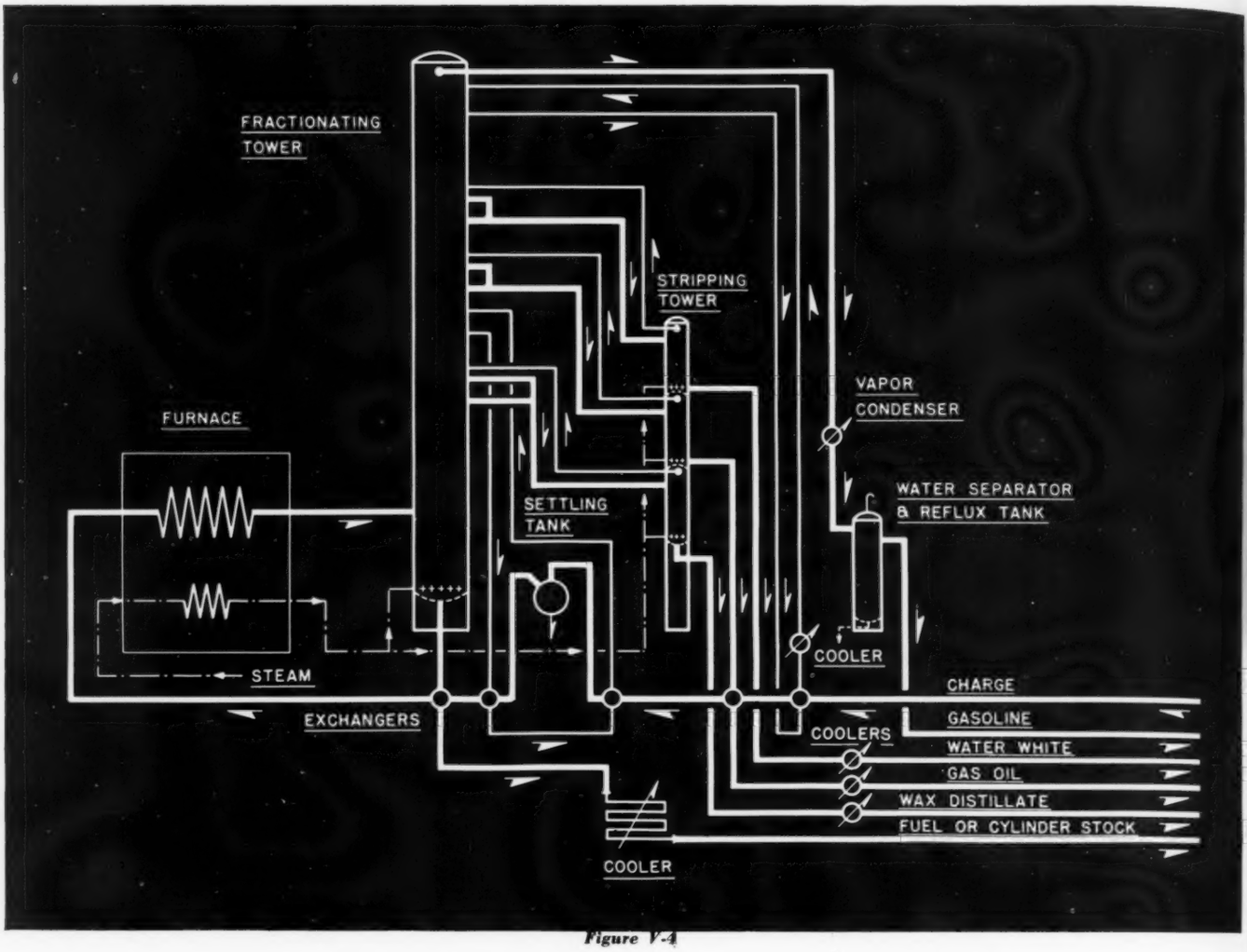
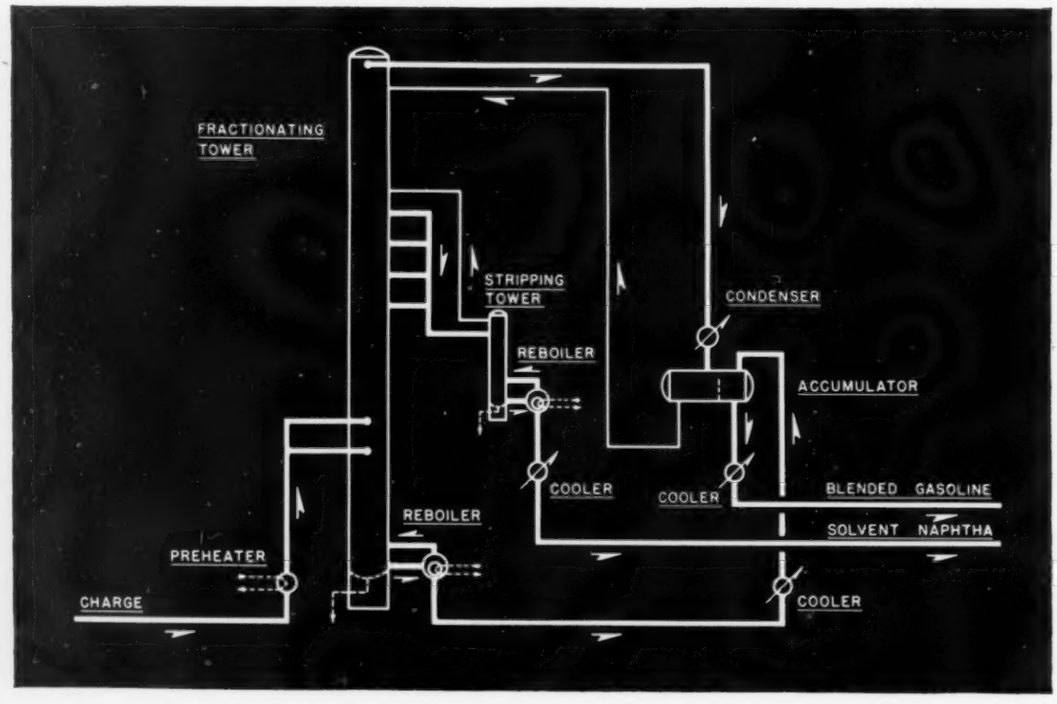


Figure V-4

Figure V-3



carry-over in the separator to a minimum. In the vacuum flash tower the bottoms are fractioned into overhead gas oil, a side-stream of cracking stock, and asphalt bottoms.

When operating as a vacuum distillation unit the flow is essentially as follows:

Charge is taken from storage and pumped serially through the circulating reflux exchangers, thence through the cracking stock side stream exchanger. The preheated charge flows through the convection and radiant sections of the tube still and discharge into the flash zone of the fractionating tower. The products from the fractionating tower are withdrawn from the proper fractionating tray as a liquid, and flow by gravity to surge tanks. The gas oil passing overhead as a vapor is condensed and flows into a mist extractor separator. The unvaporized portion is withdrawn from the reduced section at the base of the tower and pumped to storage. Sufficient superheated process steam is introduced into the stripping section of the main fractionating tower and

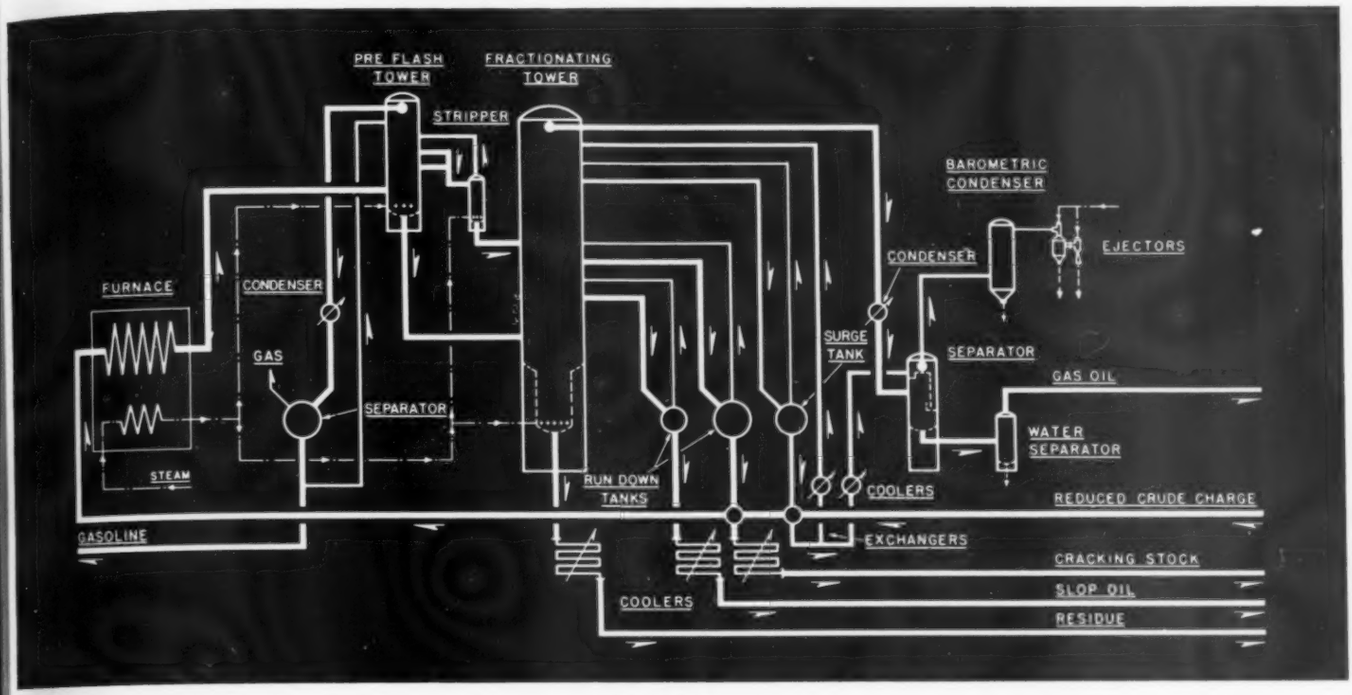


Figure V-6

provisions are made to introduce high pressure steam to the roof tubes of the tube still.

The unit is continuously exhausted by steam jet air pumps.

GENERAL DESIGN

In order to accomplish the combined operation of both pressure and vacuum on the furnace, it has been necessary to provide fittings which would give the flexibility of changing the flow from series operation when operating under presssure to a series parallel flow when operating under vacuum for production of lubricating oil distillates.

The furnace design is so arranged that this flow can be easily changed by the replacement of crossover connections which were fabricated so that they can be easily replaced, and the installation of U bends for the roof tubes which give a four to carry flow. The design is such that this changeover can be made in not more than a week.

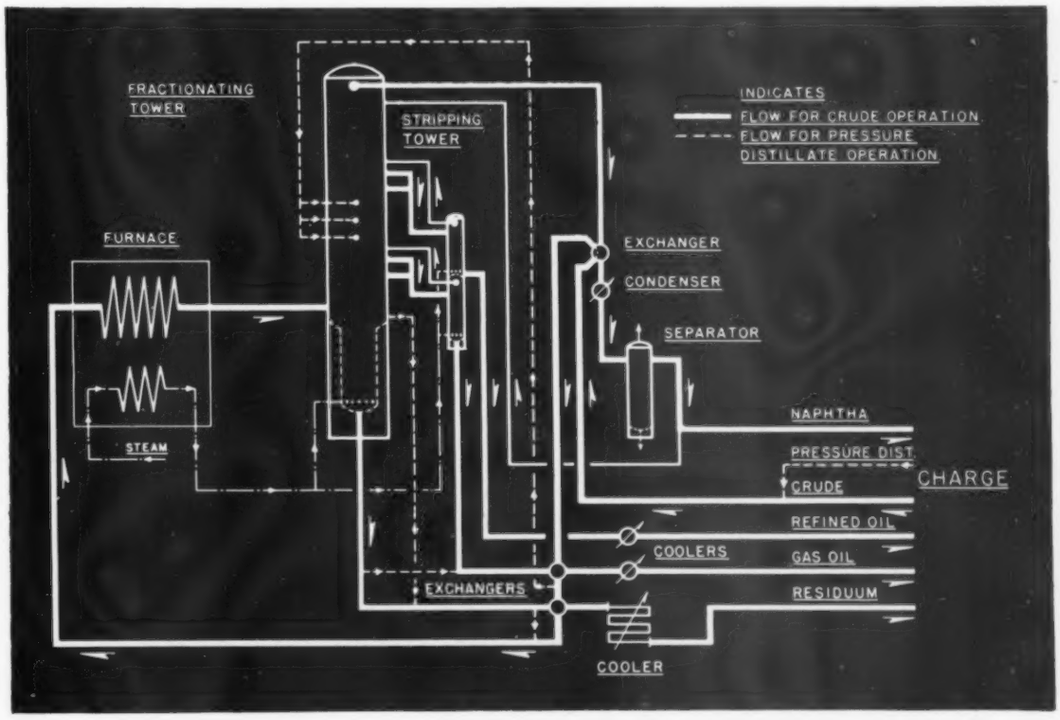
When operating under vacuum there are facilities for introducing high pressure steam into the roof tubes to effect the necessary vaporization at low absolute pressure and minimum wall outlet pressure. The introduction of a pressure pre-flash tower between the furnace and the vacuum tower permits more flexibility in the removal of any light ends produced in the furnace when operated under pressure; at the same time having the full advantage of a vacuum operation for the distillation of the heavy ends.

Size and arrangement of the vacuum fractionating tower is controlled by the vacuum distillation operation, and the furnace surface is controlled by the heat input required when operating at high pressure and temperatures for further reduction of the asphalt. This combination of equipment makes the unit an ideal one for distillation in a refinery requiring flexibility of production where various grades of heavy products are desired with facilities to take care of any changes in the market in the future.

Figure V-5

PERFORMANCE

Although the plant has been based on normal charging capacity of 4,500 bbl. per day, the tower, tube still and auxiliary equipment have been designed with a considerable factor of safety.



DAILY RUN SHEET GAS FRACTIONATION

DATE: _____ 19 7:00 AM. TEST Nº: _____ SHEET Nº: ____ CHARGING STOCK: ____

TIME	QUANTITIES												TEMPERATURES										
	FRESH FEED		WORK T'K	FUEL OIL	WET GAS	STAB. POLY DIST		METHANE	POLY GAS	POLY RECYCLE TANK	PROPANE T'K	DRY GAS	FRESH FEED		STAB-POLY DIST		RECYCLE	PROPANE	COIL OUT	EVAPORATOR		FRACT. TOWER		
	#1	#2			MANO	#1	#2	MANO	MANO				T'K 1	T'K 2	T'K 1	T'K 2				IN	OUT	TOP	INLET	BOTT
7 AM.																							
8 "																							
9 "																							
10 "																							
11 "																							
12 "																							
1 P.M.																							
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6 "																							
7 "																							
AVERAGE																							

ALCO PYROLYSIS AND THERMAL POLYMERIZATION PLANTS ARE COMMERCIALLY SUCCESSFUL—

BECAUSE—they are the fruition of years of pioneering research

BECAUSE—their design and construction is thoroughly tested in a full commercial size experimental unit before adoption in a purchaser's plant

BECAUSE—they use both refinery and natural gases as charging stock, and the saturates and unsaturates are converted into valuable gasoline blending stock of high aromatic content

YIELD SUMMARY	#1 bs.	bbls.	M.W	MOLS	MOL.W.	WTS.
CHARGE						
STAB. DIST.						
FUEL OIL						
METHANE						
POLY. GAS						

TESTS OF COMPOSITE SAMPLES	SP. GR.	UNSAT'S.	I.B.P.	50%	E.P.
CHARGE					
STAB. DIST.					

ALCO PRODUCTS

30 CHURCH STREET, NEW YORK, N. Y.

DIVISION OF AMERICAN

AND POLYMERIZATION PLANT

LOCATION: _____ COMPANY _____ ALCO PRODUCTS INC. NEW YORK N.Y.

T.	METHANE TOWER			POLY. T.		PRESSURES																MISC.
BOTT.	TOP	INLET	BOTT	TOP	BOTT.	FRESH FEED		WORK TANK	COIL OUT	EVAP. ORATOR	FRACT.	TOWERS			RE- FLUX TANK	PRO- PANE TANK	UTILITIES				POWER METER	
						TK#1	TK#2					STAR.	METH ANE	POLY			H.P. STEAM	WATER	FUEL GAS	AIR	#1	#2

ALCO Pyrolysis and Thermal Polymerization Plants Are Now Operating or Are Under Construction in the States of—

CALIFORNIA

LOUISIANA

OHIO

Also in

IRAN, JAPAN, AND THE ARGENTINE REPUBLIC

GAS ANALYSES											
	CO_2	H_2O	C_1	C_2-	C_2	C_3-	C_3	C_4-	C_4	C_5

OPERATING INSTRUCTIONS

REMARKS

INCORPORATED

ARTILLERY HOUSE, ARTILLERY ROW, LONDON, S. W. I. ENGLAND

LOCOMOTIVE COMPANY

REFINERY PROBLEMS Solved Experimentally

The Modern Pilot Plant Here Described Gives Indispensable Data for Design of Petroleum Refining Equipment and Process Work.

EARLY in its operations Alco Products, Inc. constructed and erected pilot plant equipment for the evaluation of oil stocks by the various methods for which it designs and manufactures equipment. Modifications of these pilot plant units are made currently in the continual search for more efficient performance. The principal operations represented by pilot plant assemblies are enumerated in the following tabulation and are described and discussed in some detail.

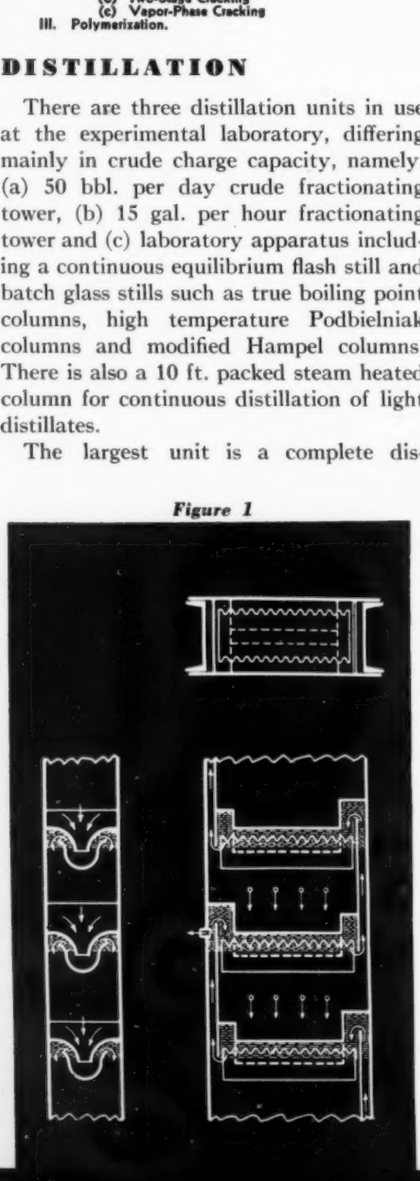
I. Distillation Processes.
II. Cracking
  (a) Viscosity Breaking
  (b) Two-Stage Cracking
  (c) Vapor-Phase Cracking
III. Polymerization.

DISTILLATION

There are three distillation units in use at the experimental laboratory, differing mainly in crude charge capacity, namely, (a) 50 bbl. per day crude fractionating tower, (b) 15 gal. per hour fractionating tower and (c) laboratory apparatus including a continuous equilibrium flash still and batch glass stills such as true boiling point columns, high temperature Podbielniak columns and modified Hampel columns. There is also a 10 ft. packed steam heated column for continuous distillation of light distillates.

The largest unit is a complete distillation unit having a crude charging capacity of 50 bbl. per day. The fractionating column is of rectangular cross-section, eight inches by 18 in. and contains 26 separate trays. The tower itself is constructed of two channels, one each forming the narrow side and joined by plates, one continuous plate on the back side and steel frame and cover plates from the front or platform side. The tower was so constructed that each tray is formed of two half troughs covered by a single Alco bubble cap (see Figure 1). The inlet and overflow weir are fixed to the sides but the cap may be raised or lowered to vary the submergence of the notched edge in the liquid on the trough. Each tray is equipped with a draw-off connection so that product can be sampled or removed from each tray. However, there are only two permanent stripping sections, each stripping section consisting of two trays with an external vapor by-pass around this section.

Figure 1



The auxiliary equipment includes automatic instrumentation, recording potentiometers and pressure points, flow indicators for superheated steam to roof tubes, reflux pump back and stripping sections. The pumps are small steam driven of the reciprocating type except the bottoms pump, which is rotary type for handling asphalt under reduced pressure. Spare pumps are provided for charging, top tower reflux, and bottoms removal. Four product transfer pumps are included as well as a dual fuel oil pumping set for firing the tube still. Tankage facilities include two 10 ft. by 16 ft. (9,000 gal. capacity) seven five feet by eight feet product tanks (1,000 gal. capacity each), and ten 18 in. by 96 in. twin receivers for measuring all products.

The tower can be operated under vacuum conditions at about half the crude capacity, i.e., 25 bbl. per day. The vacuum actuating equipment consists of a barometric and a two stage steam ejector. A flash vaporizer is manifolded to the tube still outlet so that asphalt can be produced under pressures of 15 to 25 mm. mercury absolute. The vapor line from the vaporizer is connected to the tower so that vapors can be separated into several fractions, or conducted directly to a condenser for condensation of the total overhead.

15 GAL. TOWER

The distillation unit just described requires a tank car of crude for a complete distillation investigation, which is a restriction in instances where the amount of sample available is limited. For smaller sized samples, up to several hundred gallons, a six inch tower is used. This tower is made up of sections of two trays per section, every other tray being equipped with a draw-off connection so that products can be taken from alternate trays. The design of the bubble cap, seal pan and down-flow pipe are such that they permit a larger bubble periphery than customarily formed in circular caps.

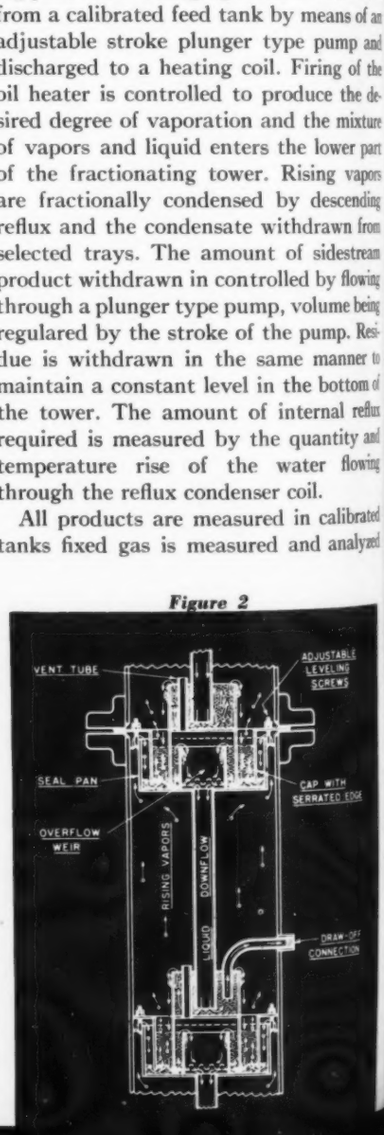
Figure 2 shows the assembly of two trays and illustrates the flow of rising vapor and descending liquid. Trays in this column are spaced 12 in. apart.

This tower is equipped with automatic top-tower temperature control by means of regulating the amount of water admitted to the internal reflux coils located in the top of the tower. An electric immersion heater in the bottom controls the amount of heat used for reboiling, current to the heater being regulated by means of an external rheostat in series with one of the heating elements.

Operation of the unit is similar to the first distillation unit and consists of the following procedure. Charging stock is withdrawn from a calibrated feed tank by means of an adjustable stroke plunger type pump and discharged to a heating coil. Firing of the oil heater is controlled to produce the desired degree of vaporation and the mixture of vapors and liquid enters the lower part of the fractionating tower. Rising vapors are fractionally condensed by descending reflux and the condensate withdrawn from selected trays. The amount of sidestream product withdrawn in controlled by flowing through a plunger type pump, volume being regulared by the stroke of the pump. Residue is withdrawn in the same manner to maintain a constant level in the bottom of the tower. The amount of internal reflux required is measured by the quantity and temperature rise of the water flowing through the reflux condenser coil.

All products are measured in calibrated tanks fixed gas is measured and analyzed

Figure 2



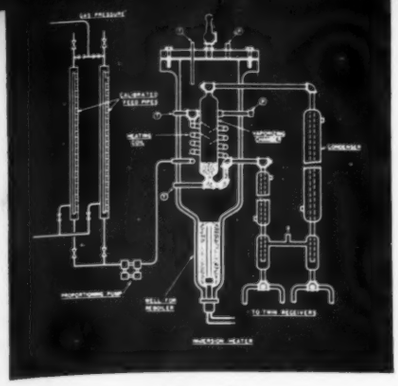


Figure 3

so that by these data a complete weight balance can be obtained as a check of the accuracy of the measurements.

The tower can be made up of as many two foot sections as may be required to effect the fractionation desired. For ordinary purposes such as separation of overhead, two side streams and a residue, sixteen to twenty trays will be sufficient.

EQUILIBRIUM FLASH STILL

Knowledge of the physical properties of fractions from a charging stock is important information when one is concerned with yield and quality of products. From an engineering and design standpoint it is equally important to know how these products may be obtained. One factor of great interest is the equilibrium flash distillation temperature required to give the desired degree of vaporization. This temperature is frequently estimated[1] from the slope of the true boiling point distillation curve, but for some stocks, particularly heavier oils, empirical data do not cover the higher temperature range, and for refractory oils or blends of radically different boiling range mixtures the deviation is serious. To cover such cases an equilibrium flash still is used and the oil in question is distilled at several temperature levels and pressures if desired and a flash curve readily established. The assembly of the equilibrium flash still used and a sectional view of the flash chamber and jacket are shown in Figure 3 and consists of the following major items:

A small capacity, 500 to 1,000 cc. per hr., duplex, positive displacement pump is used to feed the sample to the heating coil. The fixed tanks consist of two calibrated glass tubes which are filled alternately from a large supply tank and maintained under constant nitrogen gas pressure so that falling level in the measuring glass will not affect the charge rate. The heating coil and flash chamber are enclosed in a six inch shell which is reduced at the bottom to hold a 2,000 watt immersion heater. The heater is thermostatically controlled and the temperature of the vapor bath can be maintained within three degrees. The shell is built to withstand 250 lb. per sq. in. pressure so that 800 deg. F. may be attained without the vapor pressure of the heating medium exceeding the design pressure of the shell. An external heating circuit of resistance wire winding over asbestos board molded to the shell, covered by magnesia insulation prevents heat losses and maintains constant and uniform temperature within the shell. Temperature readings of the coil outlet, flash chamber inlet, vapor and liquid residue outlet as well as the surrounding vapor agree within a few degrees. The vapor outlet and residue lines are oversize so that very little pressure drop occurs, less than can be detected on an ordinary mercury manometer. The residue draw-off line is higher than the bottom of the flash chamber, hence forms a liquid seal at this point. The drain line is large enough to prevent syphoning of residue. The overhead vapor line and residue drain lines pass through condensers and coolers and drain into graduated receivers. The vent line from each receiver is joined to a pressure reservoir so that the same pressure exists in both receivers.

The operation consists of charging a uniform quantity of feed, heating it to the desired temperature at a constant pressure and taking readings of the overhead condensate and liquid residue. Readings are continued until satisfactory consistent results are obtained.

BATCH STILLS

The laboratory assay stills of glass apparatus consist of three necked flasks bearing packed columns of various dimensions and containing packing of effective fractionating performance. The more precise columns, that must of necessity run at slow rates, are used to establish distillation curves, but for actual analysis of cuts, a five liter flask, having a one inch by 24 in. column packed with jack chain is found convenient for evaluation work. With this arrangement, five percent cuts can be collected and inspected for common physical properties. The distillation can be continued in the same apparatus under vacuum to recover lubricating oil stocks. Data of the properties of five percent cuts throughout the vaporizable range, plotted against the mid-percent point of each cut will make it possible to predict with reasonable accuracy the yield of any product to be recoveedr from a given charging stock.

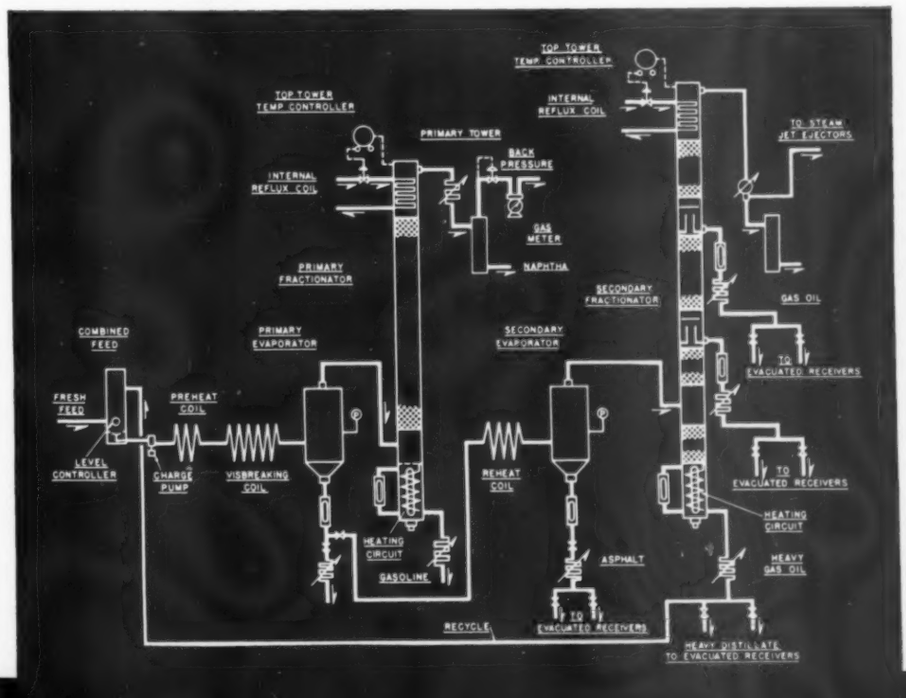
CRACKING

With the aid of the experimental and research tools described in the preceding section, it is possible to arrive at efficient and economical design of fractionating equipment. Of greater commercial value and certainly more complex are the problems of cracking plant design and operation. In this field the designing engineer is dependent upon experimental data and pilot plant tests to assist in evaluating changing stocks into yield and quality of intermediate and final products and to establish operating conditions. In order to furnish the answer to many of these questions and likewise for the purpose of investigating new and improved processes the experimental cracking equipment to be described was assembled. Since there are many different cracking methods the experimental equipment was made as flexible as possible and at the same time to parallel as closely as possible plant operating conditions. Examples of three cracking processes are shown in Figures 4, 5, and 7 and described briefly in the following sections.

VIS BREAKING

The charging stock is forced by nitrogen pressure continuously to the combined feed tank. A small level control float admits sufficent fresh feed to compensate for the

Figure 4



[1]Piromov and Beiswanger (Am. Pet. Inst. Bulletin 10, p. 52).

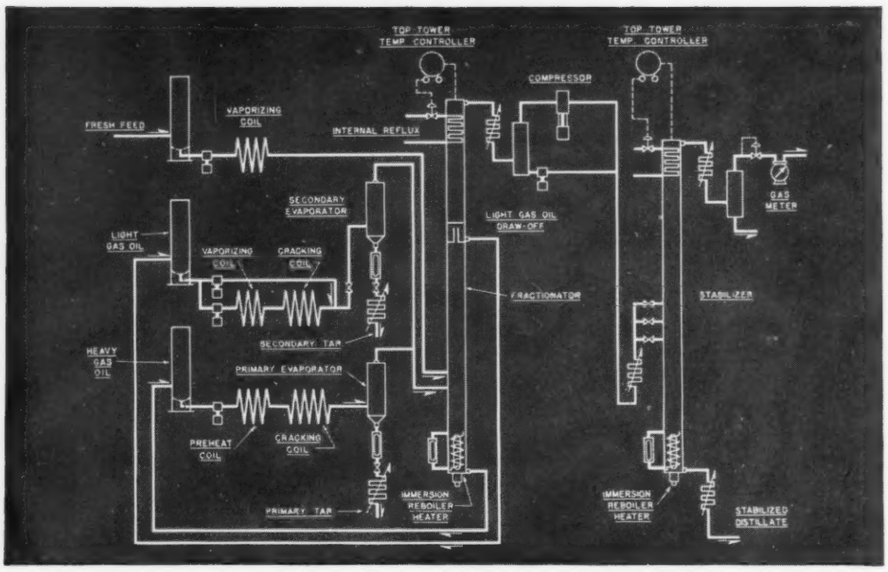


Figure 5

amount of fresh feed and recycle stock removed by cracking or as fuel oil. A high pressure (1,000 lb. per sq. in.) adjustable stroke proportioning pump withdraws feed from the combined reed tank and pumps the mixture through the preheating coil. Temperature of the charge leaving the coil is controlled by the firing rate and is set short of cracking temperature. The charge then flows to another coil where it is quickly brought to cracking temperature. A thermocouple placed in the coil a short distance from the inlet will give an intermediate point that indicates rate of heating. The charge continues through the rest of the coil at substantially vis-breaking temperature. Temperature of the main oil stream and the tube wall temperature at the outlet are measured, as well as the lead-bath temperature. In case the thermocouple wells become coked, the lead-bath temperature is sufficient indication to hold a uniform temperature throughout the experiment.

Products from the coil are flashed in a vertical evaporator which separates vapor and residue. The evaporator may be carried under system pressure; or in case of high pressure imposed on the viscosity breaking coil, the pressure is reduced at the coil outlet. Vapors from the evaporator flow to a fractionating tower which separates fixed gases from condensate. Residue is drawn from the bottom of the evaporator through the sight glass in which a liquid level is maintained and discharged through a reheating coil. The function of the reheating coil is to add sufficient heat to vaporize all constituents boiling below asphalt. The reheated charge is flashed in a low pressure evaporator which is usually held under vacuum. Vapors from the evaporator flow to a second fractionating tower, also maintained under vacuum, and there are separated into different boiling range fractions. The fractionating tower bottoms, being the heaviest distillate (practically all of which boils above 600 deg. F.) may be returned to the feed tank for additional viscosity breaking, or withdrawn from the system as a heavy gas oil. Normally, the products of viscosity breaking are gas, gasoline, light gas oil (400-600 deg. F. boiling range), heavy gas oil (or recycle stock) and vis-broken residue.

Liquid fractions collected over the period of a test are seldom of boiling range specifications, so that at the end of a test they are mixed together in the same proportions as they were produced and redistilled through the 15 gal. per hour still previously described to provide cracking stock for additional tests.

HEATING COILS

In one respect, small scale equipment, i.e., units charging 5-20 gal. per hour, are apt to fall short of realizing commercial conditions, and that is in the flow through heating coils. Invariably pilot plant heating coils are made of ¼ inch to ½ inch tubing so that an average flow of 10 gal. per hour will be an exceedingly low lineal or mass velocity and in many instances, where vaporization is slight, viscous flow conditions are likely to prevail.

The disadvantages of viscous flow can be largely offset by careful limitation of tube wall so that film cracking is greatly reduced. This is made possible by use of coils submerged in molten lead baths as illustrated in Figure 6. Temperature readings of the tube wall, oil stream and lead-bath show there is only 25 to 40 deg. F. difference between coil outlet and lead-bath. The heat transfer rate in a coil of this type is higher than rates obtained by convection and radiation effects in a pipe still heater, so that it is necessary to install intermediate thermocouples in cracking coils to assist in establishing the heating curve and time factors. By dividing a coil into several parts and installing each coil in a separate bath, the heat rate and soaking time can be more closely controlled.

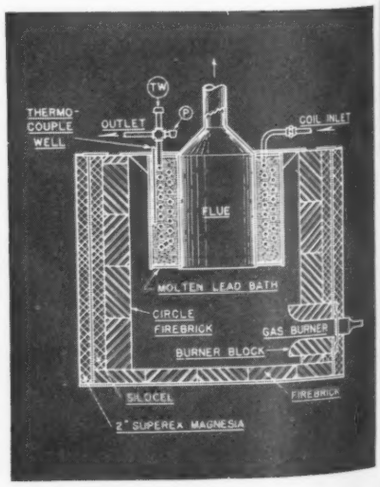
MULTI-STAGE CRACKING

The character of the charging stock to a cracking process governs the type of process to be employed. A charging stock containing much asphalt is usually subjected to a viscosity breaking operation such as described. Gas oils collected from such an operation serve as charging stock for cracking operations, or a charging stock initially low in asphalt content may be used. Occasionally a naphtha fraction is segregated for cracking by a reforming process.

One type of cracking, involving two coils, one for heavy gas oil and one for light gas oil, is shown diagrammatically in Figure 5. The operation of the pilot plant unit is briefly described in the following section.

Charging stock is fed at a uniform and predetermined rate, based by experience with similar stocks, through a vaporizing coil and heated to vaporizing temperature. The outlet of the coil enters the fractionating column above the flash zone where it is fractionated into two or more cuts, gasoline overhead, light gas oil, and heavy gas oil. Light gas oil is drawn off the upper accumulator pan and flows by gravity to a surge tank; likewise heavy gas oil is drawn from the base of the tower to the other surge tank. Each charging stock is pumped through short preheating coils where the temperature is raised almost to cracking temperature, then flows to the cracking coil. The temperature is raised quickly to

Figure 6



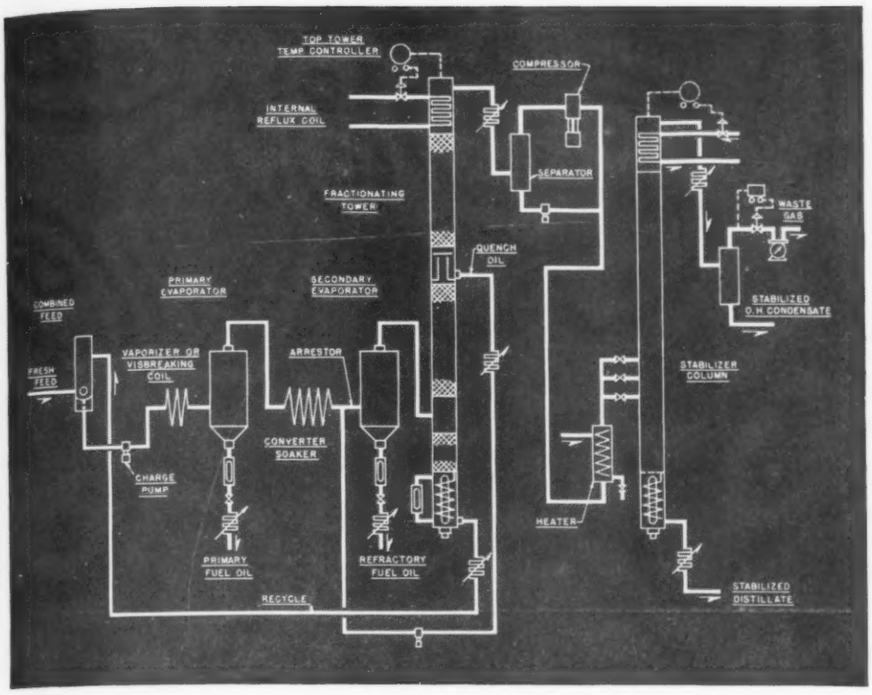


Figure 7

cracking and held at this temperature (soaking) for the remainder of the coil volume. The heavy gas oil coil discharges to an evaporator in which tarry material condenses and is withdrawn. Vapors from the evaporator then enter the flash zone of the fractionating tower.

The outlet of the light-oil coil is normally quenched with some light distillate such as clean charging stock or light gas oil, in order to arrest the reaction and prevent coke and gas formation. Quenched products enter the secondary evaporator where refractory tar is separated and withdrawn. Vapors leaving the evaporator enter the main fractionating tower for fractionating into product and recycle stocks.

The mixture of vapors from the three coils, enter the tower and are fractionated; gasoline and gas leave the top of the tower as vapors; there is a side stream of recycle and virgin gas oil, and a tower bottoms consisting of recycle and virgin heavy gas oil. Overhead products pass through a condenser and cooler and enter a gas separator. Gases are removed by a compressor and liquid by an adjustable stroke pump, and both liquid and gas are discharged at the pressure of the stabilizer. The mixture passes through a steam heater before entering the stabilizer column. Stabilizer is equipped with an electrical immersion heater and a top tower temperature controller. Light hydrocarbons are separated from the liquid product, in this case producing gases and stabilized distillate of desired vapor pressure.

Vapors leaving the top of the stabilizer column pass through a condenser coil where the heavier constituents are condensed and collected in a receiver for measurement and sampling and may be saved for subsequent polymerization tests or discarded. Fixed gases escaping from the receiver consisting chiefly of ethane, ethylene, methane and lighter, pass through the pressure regulator valve to the gas meter.

POLYMERIZATION

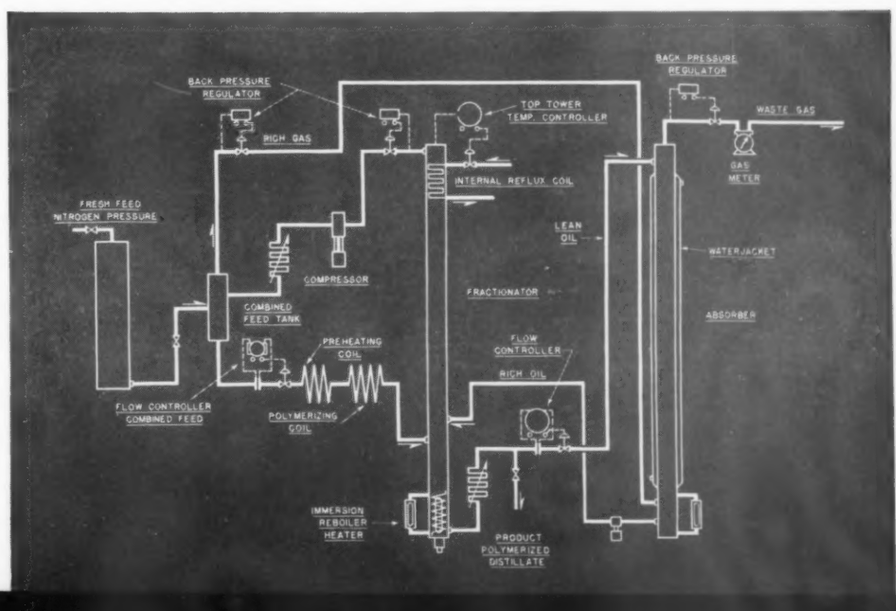
For several years polymerization of refinery gases or pyrolysis-polymerization of highly saturated gases has occupied a prominent place in refinery developments. As in cracking, the reactions, operating variables (principally temperature and time elements), composition of charge and the effect of these factors upon yields and properties of products are complex and the design of equipment for such processes is based to a great extent on the result of experimental data and research. In order to solve many pertinent problems and establish the validity of certain physical-chemical theories the polymerization pilot plant was constructed as an important and necessary research tool. The process has been subject to rapid development and improvement and in its present state is represented diagrammatically by Figure 8.

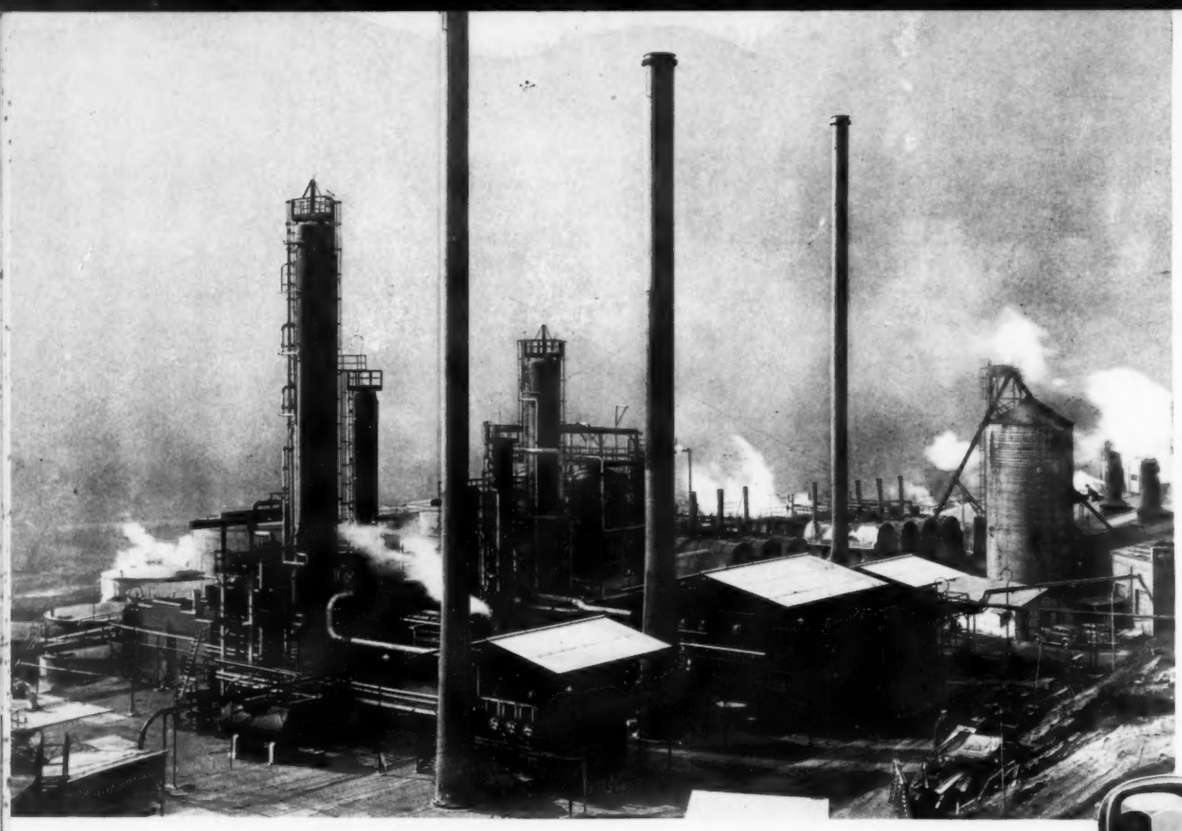
The process as employed consists of the following operations. A large storage tank capable of holding sufficient feed stock for a series of tests is held under nitrogren pressure, a few pounds higher than the combined feed tank pressure. This will permit additions of fresh feed to the combined feed tank in order to maintain a constant level. The mixture of fresh feed and recycle stock is fed through the flow controller at a fixed uniform rate to a preheating coil located in one lead-bath and then directly to the reaction coil located in a separate bath. The reaction, though exothermic, does not develop too much heat in the pilot plant equipment. The reaction coil discharges to the base of the fractionating tower below the liquid level where the temperature is immediately reduced. Excess heat entering the tower is removed by the top tower temperature controller and the addition of rich oil from the absorber. Vapors leaving the top of the fractionator are compressed to the combined feed tank pressure, pass through a coil where recycle liquid condenses and flows to the combined feed tank. Uncondensed gases flow to the absorber tower and rise through the down-coming absorbing oil.

Liquid drawn from the base of the fractionator passes through a cooler and excess liquid, over and above that required to hold a level in the tower, is drawn from the system as product. A constant stream of liquid is fed to the top of the absorber where the heavier constituents are absorbed and returned to the fractionating tower. Waste gas passes from the top of the absorber through the pressure regulating valve and meter.

As in cracking processes, various modifications are possible by slight rearrangement of flow and equipment. ■ ■ ■

Figure 8





Type 1000 box type straight port supplied with either plain or deflector plug.

OHIO REFINERY RETURN BENDS

For many years the various Ohio designs of return bends have played an important part in the satisfactory operation of refinery cracking units.

Rugged design throughout, especially in top construction and holding members, is a feature of all Ohio types and is one of the many reasons for their long trouble-free life.

The three types shown here have been very popular and the choice between them depends upon what features are most desired by refinery engineers.

Submit operating conditions and tube size and recommendations will be given.

Type 1600 is fitting with radius port equipped with deflector plugs for streamline flow — set collar type closure.

Type 2000 full streamline sectional bend with single tube replacement feature. Special Ohio connection holds housings in proper alignment.

The OHIO STEEL FOUNDRY COMPANY

ENGINEERS ∽ FOUNDERS ∽ MACHINISTS

SPRINGFIELD, OHIO

General Office: LIMA, OHIO — *Plants:* LIMA, OHIO — SPRINGFIELD, OHIO

REFINERY STEEL BY BEAIRD

The J. B. Beaird Corporation's contribution to Alco Product's refinery development is chiefly the fabrication of structural steel. We are proud to have taken part in a number of Alco's modern installations in the United States and abroad.

Located in Shreveport, Louisiana, in the heart of the mid-continent oil field, our plant is advantageously located for serving the refineries in this territory. In addition, the location near the ports of New Orleans and Houston has led to sizable exports. In recent years we have been favored with considerable foreign business.

Our plant facilities include a most modern structural fabricating shop, a plate shop capable of working plate up to a thickness of 2 inches, an electric steel foundry, which is supervised by a competent staff of metallurgists, who are aided by the facilities of complete chemical, physical, and metallurgical laboratories.

Our electric steel foundry specializes in production of high pressure and high temperature flanged ring-joint fittings, special nozzles, man ways, corrosion resistant hot oil pump-liners, and many special products to meet unusual conditions encountered in refinery operation.

Our machine shop is equipped to manufacture all classes of refinery fittings; heavy pump and gas engine repairs are a specialty of our plant.

The fabrication of steel for furnace construction is supervised by an engineering department, thoroughly acquainted with every phase of this work.

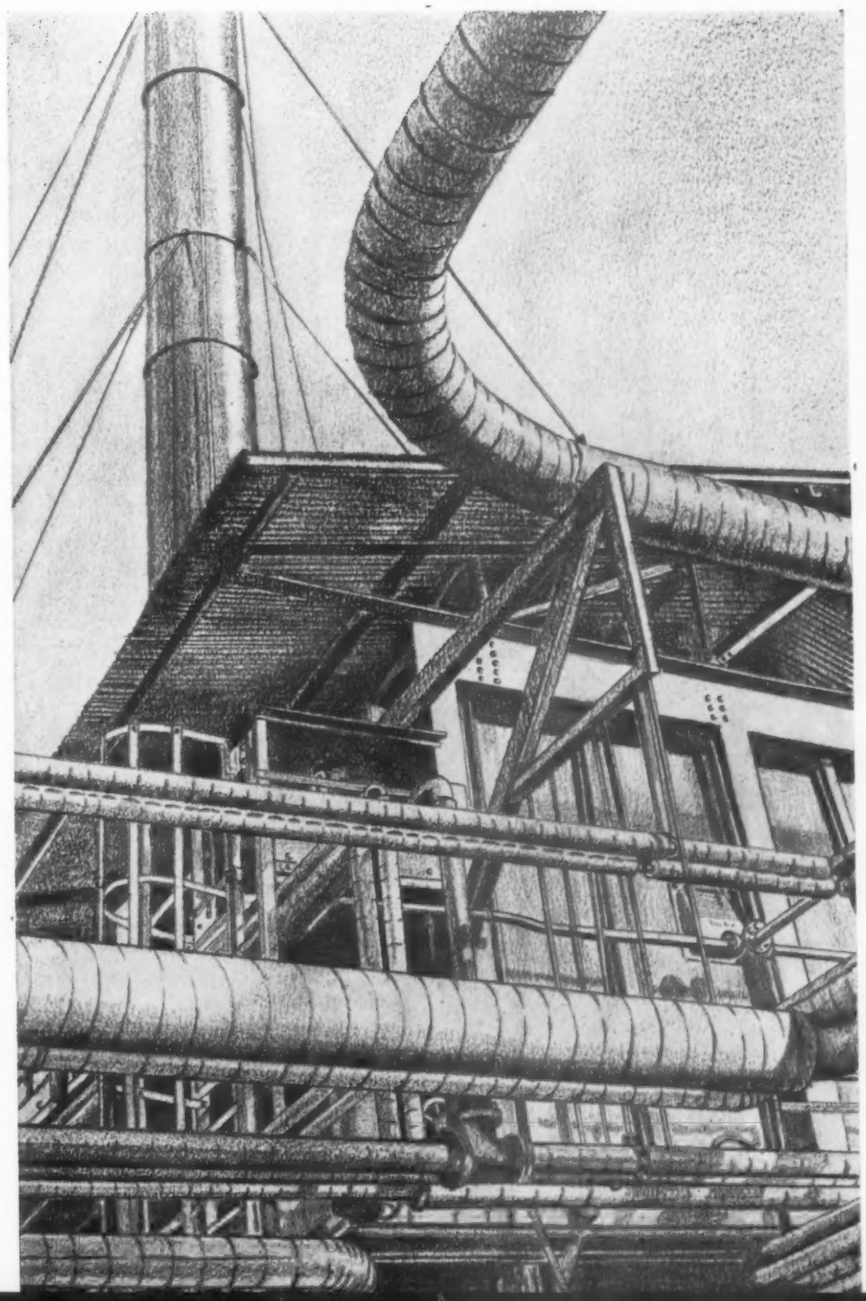
We are manufacturers of equipment for the drilling and production divisions of the oil industry, in addition to our many products used by the refinery trade.

The J. B. Beaird Corporation is always glad to receive inquiries concerning materials for refinery construction or plant maintenance work. Our engineers and laboratory personnel will be glad to aid you in any problem that requires special development in the field of alloys. Our staff will gladly cooperate with your plant engineers.

The J. B. BEAIRD CORPORATION

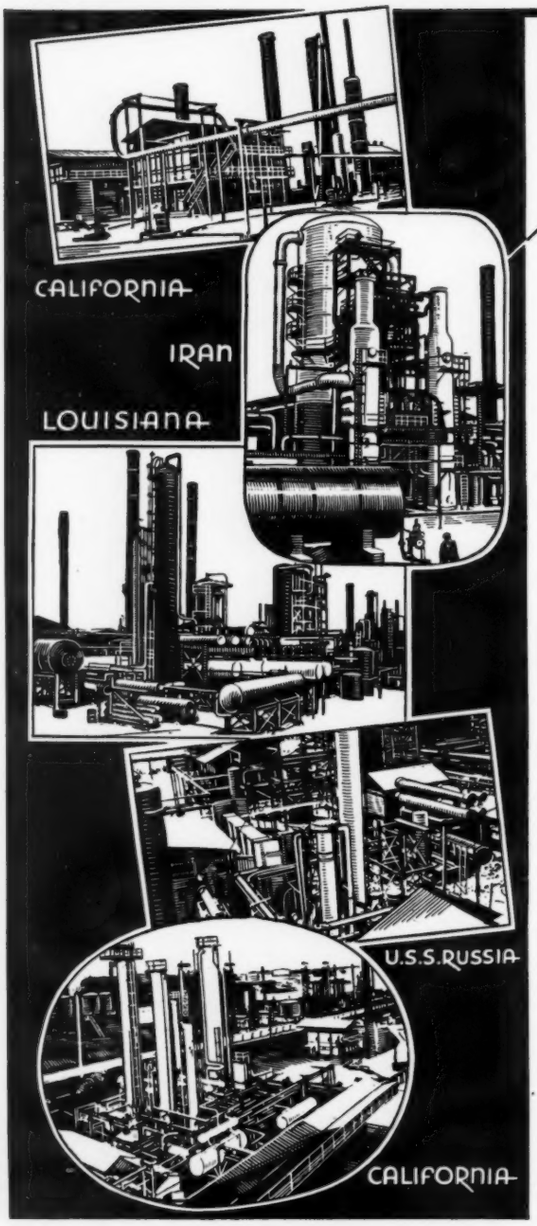
SHREVEPORT, LOUISIANA

The J. B. Beaird Corporation Serves Alco Products by Fabrication of Refinery Steel to the Exacting Specifications Required by This Organization.



From EVERY DIRECTION

COMES PROOF OF KEY SUPREMACY . . .



THE WORLD-WIDE ACCEPTANCE OF KEY REFINERY FITTINGS IS A TRIBUTE TO KEY SERVICE AS WELL AS KEY PRODUCTS

From the day a refinery is first conceived—long before plans take final shape in finished blue prints—Key Engineering service becomes of inestimable value.

Working with the contractor and the refinery engineering staff, Key engineers place at their full disposal records of the newest, most advanced developments in refinery fittings. By calling in a Key engineer at the inception, it is frequently possible to effect great economy through the use of one of the many standard Key units by minor changes in plans. This feature of Key service should not be overlooked.

Key service is as inclusive of the industry as it is efficient and complete. From the erection of the simplest of skimming plants to an involved hydrogenation process, Key has definite recommendations to make—backed by experience gained from successful installations elsewhere.

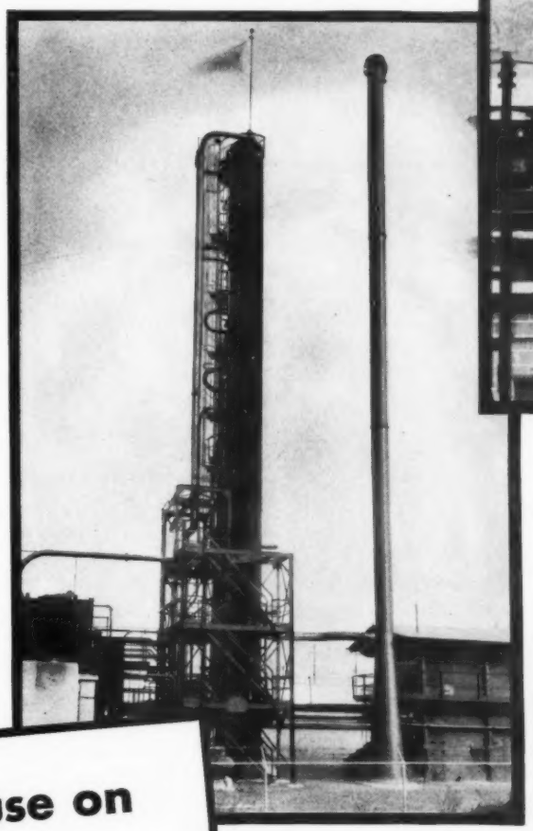
We are proud of the fact that Alco Products, Inc. have selected Key fittings for the refineries illustrated here—as well as many others the world over. Only the finest fittings are safe to use in installations tens of thousands of miles away from the factory where problems of defective design or workmanship would be magnified many times over. Alco's selection is evidence of their own meticulous care, as well as a sincere tribute to the quality of Key fittings.

KEY COMPANY

EAST ST. LOUIS ILLINOIS

EAGLE INSULATION CUTS OPERATING COSTS ON ALCO JOBS

Operating efficiency has been maintained in these Alco Units with exclusive use of Eagle Insulating Materials.

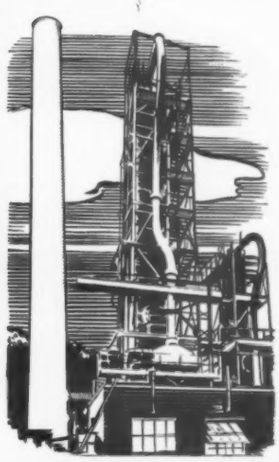


On more and more Alco refining units, Eagle Materials are being used as the *only* insulation.

The latest job on which Eagle Insulation was specified exclusively is the new Houston unit furnished to the Shell Oil Company!

High efficiency and a reputation for dependable service have paved the way for this remarkable acceptance. Call Eagle-Picher the next time you have an insulation requirement. Eagle-Picher will serve you efficiently and well.

THE EAGLE-PICHER LEAD COMPANY
Cincinnati, Ohio



SELECTED for use on Alco Equipment

Towers and exchangers are covered with Eagle Blankets, ½-inch coating of Eagle Super "66" Plastic Insulation, and weatherproofed with Eagle Insulseal.

Piping is completely insulated with Eagle High-Temperature covering, and weatherproofed.

Structural supports are fireproofed with Eagle Fire-Kote.

SEE OUR CATALOG IN SWEET'S

EAGLE INSULATING SERVICE FOR OIL REFINERIES

W-S FORGED STEEL FITTINGS

are giving dependable service in the following ALCO built refineries throughout the world: Anglo-Iranian, Abadan, Iran; Y.P.F., Argentina; Tidewater Associated, Avon, California; Shell Petroleum, Houston, Texas; Humble Oil, Tomball, Texas.

W-S Fittings are bored from solid steel forgings having specified chemical and physical properties and that in itself recommends their use for services involving high pressures and temperatures—but W-S quality goes further—they embody improvements brought about by advanced design and manufacturing methods. In the cross-section view above, note the uniform thickness of the wall, a feature that, through the use of modern machine tool equipment, is definitely controlled in all sizes and types of fittings. The specified minimum thickness of walls is based on a study of the corrosive and erosive action of various fluids and, consequently, W-S Fittings offer a greater factor of safety when used under even the most severe conditions.

Openings are of the same area as pipe of like size and permit free unrestricted flow. Wide heavy bands and sharp accurate threads perfectly aligned provide for easier installation and insure tight joints.

For complete satisfaction on lines carrying oil and gas, under high pressures or temperatures, use W-S Forged Steel Fittings. You will find that they not only give better service but assure lower costs in pipe line maintenance.

W-S FORGED STEEL FITTINGS

THE WATSON-STILLMAN CO. ROSELLE, N. J.

ALCO INSULATES WITH WEBER'S SPECIAL 2-4-1

—the Last Word in Insulation

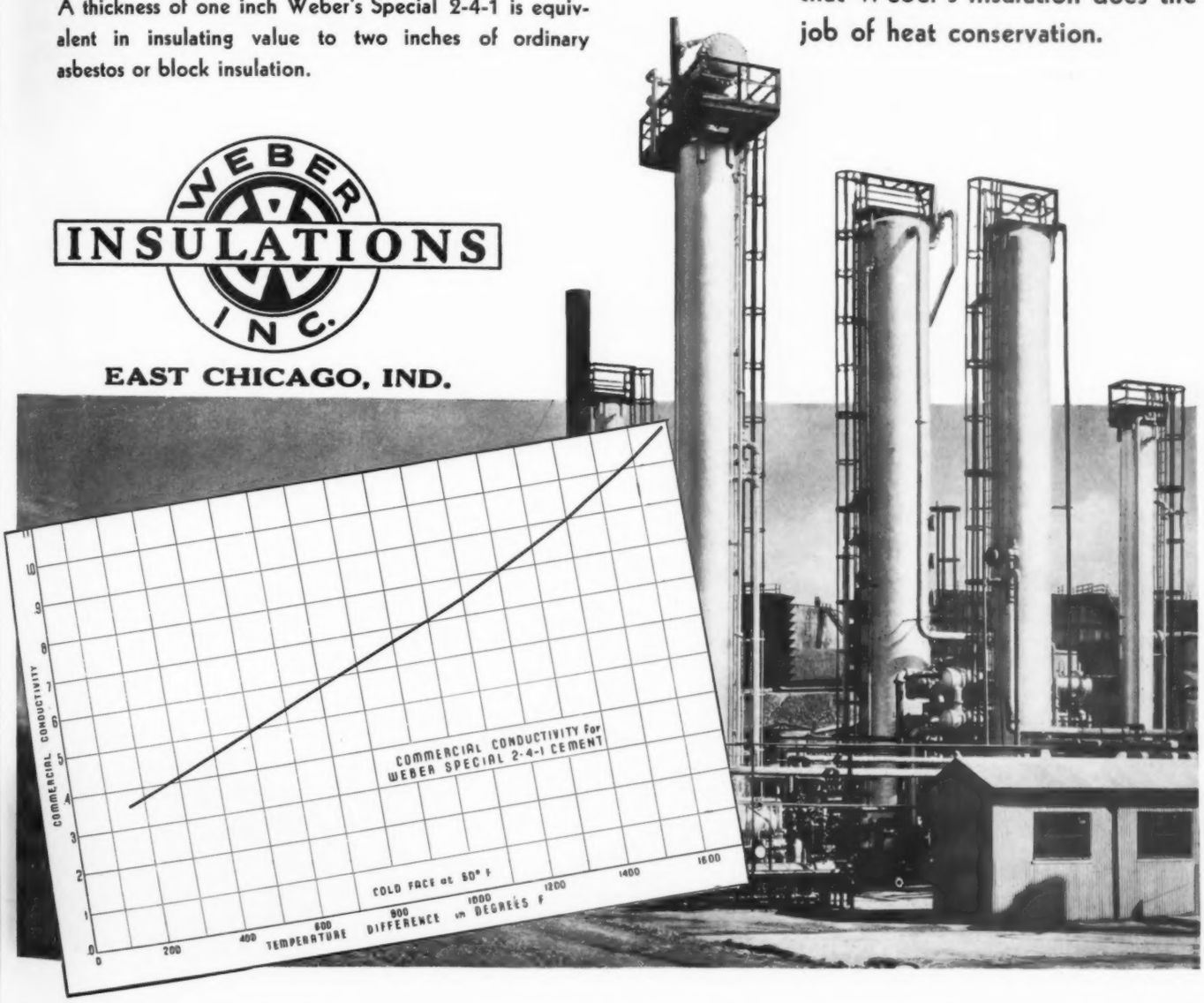
Weber's 2-4-1 is easy to apply. Simply mixed with water it forms a thick plastic consistency which can be applied by hand and smoothed with a trowel. It sticks to either hot or cold surfaces—is 100% reclaimable up to 1100° Fahrenheit—has a spreading capacity approximately 1000 square feet to the ton—a working temperature up to 2000° Fahrenheit, and can be used on all types of installations with equally satisfactory results.

A thickness of one inch Weber's Special 2-4-1 is equivalent in insulating value to two inches of ordinary asbestos or block insulation.

Owners and operators of Alco-built refining units are finding that Weber's Insulation does the job of heat conservation.

WEBER INSULATIONS INC.

EAST CHICAGO, IND.



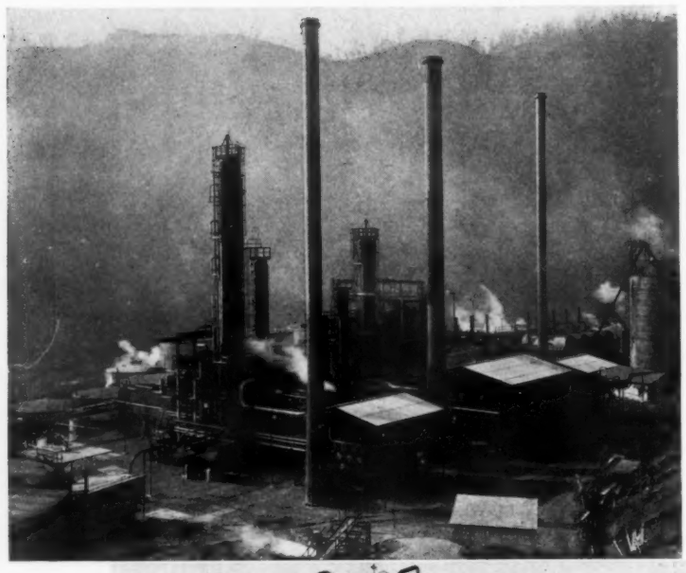
ALCO Cuts "DOWN TIME"

with

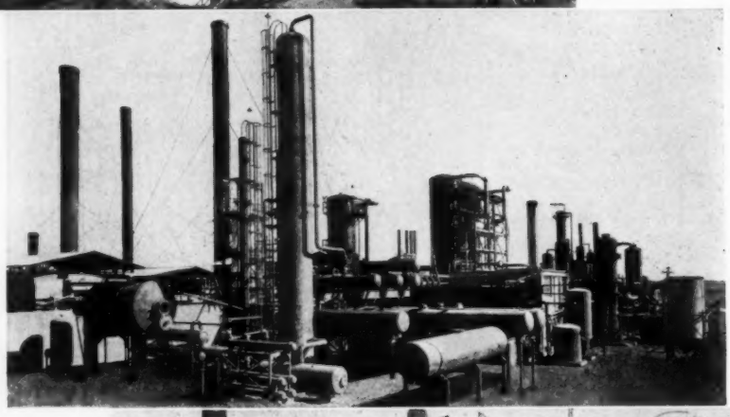
AIRETOOL

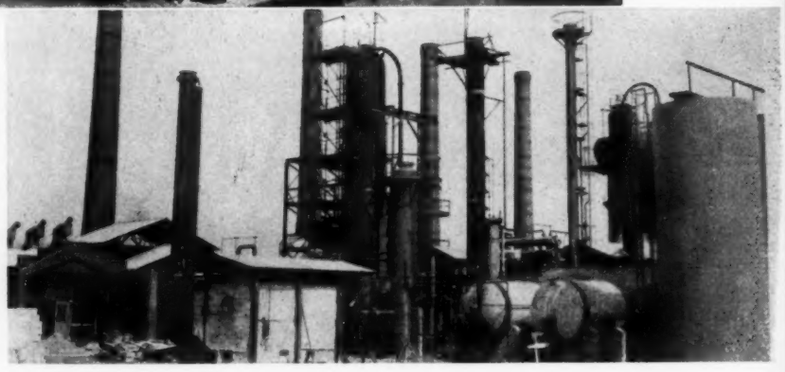
CLEANERS

THE STANDARD IN MANY REFINERIES



Airetool super powered motors having double exhausts and equipped with self-feeding cutter heads solve all refinery cleaning problems. Airetool cutter heads successfully cope with all conditions and carbon thicknesses. They clean quickly and thoroughly and insure long life of tubes.

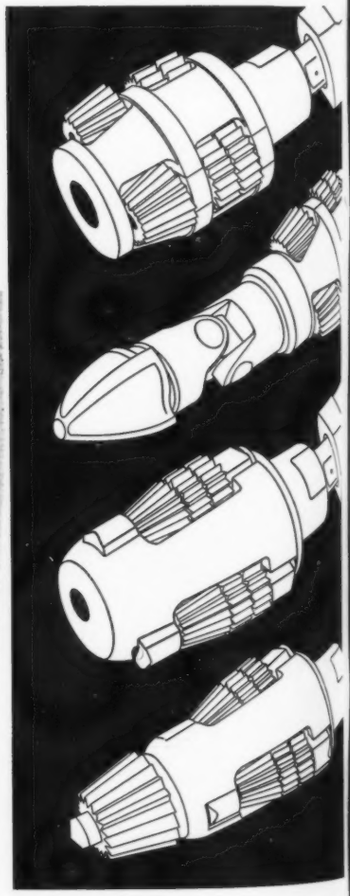




Top — illustrates plant of Pure Oil Company, Cabin Creek, W. Va.

Center — illustrates plant of Atlas Pipeline Corp., Shreveport, La.

Lower — illustrates plant of Pure Oil Company, Toledo, Ohio.



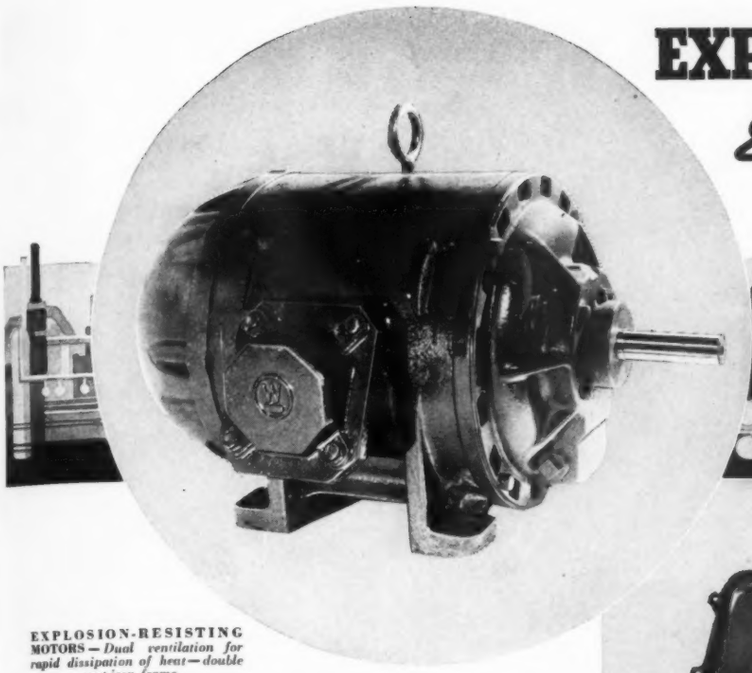
Airetool cleaners for every refinery need from small heat exchanger tubes to large vapor and transfer lines.

THE AIRETOOL MFG. CO.

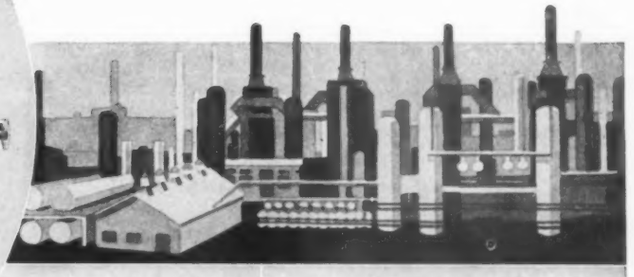
SPRINGFIELD, OHIO

EXPLOSION-RESISTING

Electrical Equipment



EXPLOSION-RESISTING MOTORS—*Dual ventilation for rapid dissipation of heat—double cast iron frame.*



EXPLOSION-RESISTING LINESTARTER—*Air break or dry type—de-ion arc quenching features.*

EXPLOSION-RESISTING LINESTARTER—*Oil-immersed type—special housing—arc-quenching with de-ion oil-immersed disconnect.*

IT CERTAINLY IS GRATIFYING TO KNOW THAT WESTINGHOUSE BUILDS SO **COMPLETE** A LINE OF EXPLOSION-RESISTING ELECTRICAL EQUIPMENT FOR THE REFINERY.

YES, AND IT HAS BEEN THEIR PLEASURE TO COOPERATE WITH **ALCO PRODUCTS, INC.** AND ALL OF THE KEY REFINERY MANUFACTURERS IN SOLVING THEIR ELECTRICAL PROBLEMS

Oil men the world over favor Westinghouse explosion-resisting electrical equipment, because it is a *complete* line, designed to conform with high Westinghouse standards . . . because it satisfies every electrical need encountered in refinery installations. They favor Westinghouse because they know that this line of explosion-resisting motors, linestarters and de-ion breakers is truly economical and assures trouble-free refinery operation.

Skilled Westinghouse engineers will be glad to answer your questions on refinery problems, or help you design equipment for your special needs. Complete information on Westinghouse Explosion-Resisting Equipment will be sent to you upon request.

WESTINGHOUSE ELECTRIC INTERNATIONAL COMPANY
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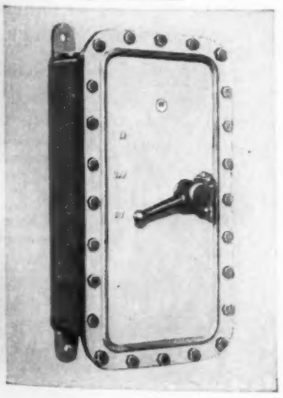
EXPLOSION-RESISTING DE-ION BREAKER—*External operation—arc-quenching—trip-free unit protects against overload.*



AN UNBEATABLE COMBINATION

EXPLOSION-RESISTING DESIGN + WESTINGHOUSE DEPENDABILITY + WESTINGHOUSE ENGINEERING SERVICE

Westinghouse

ELLIOTT STEAM JET EJECTORS ARE USED ON THE ALCO VACUUM UNITS IN THE ANGLO-IRANIAN REFINERY AT ABADAN, SHOWN BELOW, AS WELL AS ON ALCO UNITS IN MANY OTHER REFINERIES

SECURITY *in these essential functions*

Everyone appreciates the feeling of security when he puts a job into experienced and competent hands. Because of the Elliott Company's long specialization in the manufacture and application of certain equipment, petroleum refineries know that the use of Elliott equipment insures the success of that particular phase of refinery operation.

MAINTAINING VACUUM

Maintaining Vacuum — Elliott steam jet ejectors and condensing equipment are insuring dependable and economically maintained vacuum on vacuum units of all kinds in refineries all over the world.

CLEANING TUBES

Cleaning Tubes — Lagonda and Liberty tube cleaners are standard equipment in refineries everywhere. They are built in types and sizes for cleaning all of the various tubes and pipes around the refinery.

PUMP DRIVES

Pump Drives — Elliott steam turbines have found particular favor in refineries for driving all sorts of pumps. Elliott steam engines are also used for certain types of pumps, as well as Elliott electric motors, built in a complete line over 50 hp.

POWER PLANT EQUIPMENT

Power Plant Equipment — Elliott deaerating feed-water heaters, condensers, turbine-generators, engine-generators, strainers, separators, etc.—all of a broad line of power plant equipment, have excellent performance records in refinery plants.

Q-1045

ELLIOTT COMPANY PITTSBURGH, PA., U.S.A.

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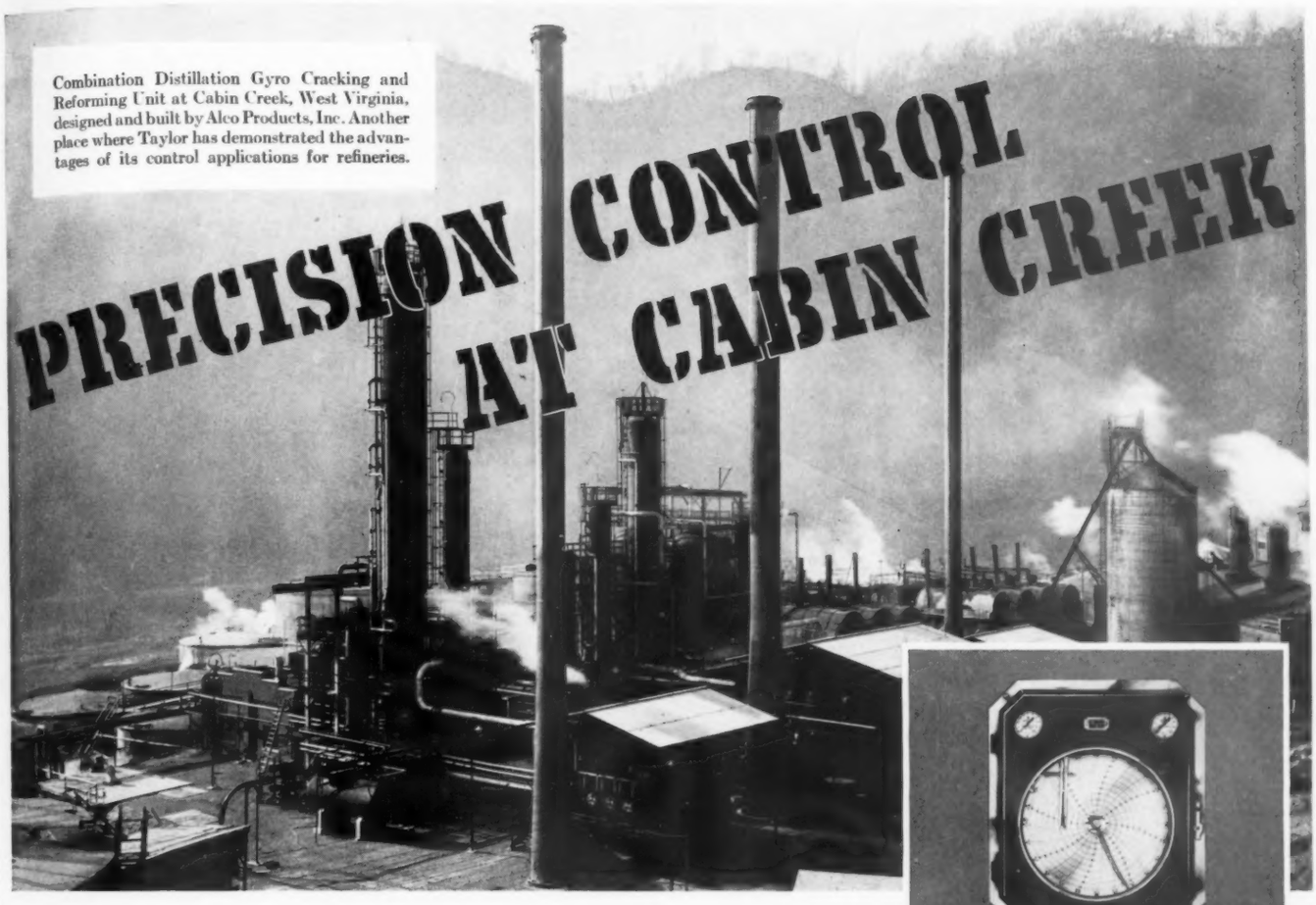
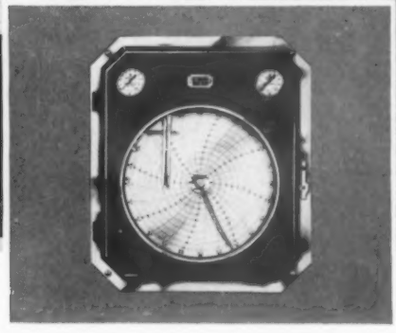
ELLIOTT REFINERY AND POWER PLANT EQUIPMENT



Combination Distillation Gyro Cracking and Reforming Unit at Cabin Creek, West Virginia, designed and built by Alco Products, Inc. Another place where Taylor has demonstrated the advantages of its control applications for refineries.

PRECISION CONTROL AT CABIN CREEK



FOR REFINERY TEMPERATURE CONTROL this Taylor Fulscope Recording Controller with its original Universal Sensitivity Adjuster provides the means of getting the one best throttling range. The Taylor Dubl-Response Control Unit on the Taylor Motosteel Evenaction Valve (below) maintains the control point in spite of load changes and assures precision valve action. The Taylor Valv-Precisor on a Motosteel Valve provides precision valve action where "reset" is not required. Write for full data on these outstanding Taylor Instruments.

Taylor Engineers and Control Systems help ALCO Products give cracking plant exact temperature and flow control

IN THIS Alco Combination Distillation Gyro Cracking and Reforming Unit at Cabin Creek there is today no question about close control of temperature, flow and pressure. Taylor engineers, with their full knowledge of control applications in the country's largest and most up-to-date plants, cooperated to help assure the highest gasoline yield and the uniform quality of all other products.

Six Taylor Fulscope Recording Controllers keep close watch over temperatures. Each controller operates with a Taylor Dubl-Response Control Unit on a Taylor Motosteel Evenaction Valve to maintain exactly the desired top tower and reboiler temperatures.

Twelve Taylor Fulscope Flow Controllers with Taylor Valv-Precisors on Motosteel Evenaction Valves guard rate of flow at various stages all through this cracking unit. And Five Taylor Pressure Controllers with Motosteel Valves hold back pressures and reduced pressures constant.

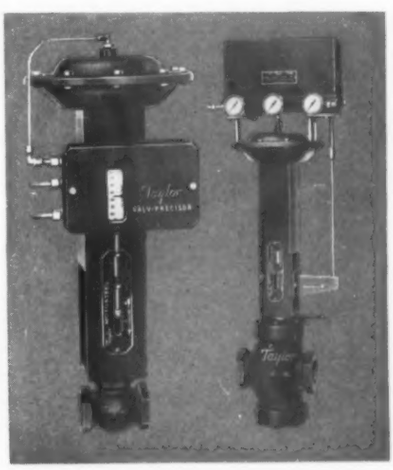
The successful results following installation of Taylor Temperature, Pressure, Flow and Liquid Level Control Systems in many plants make it certain that YOU can obtain the control best suited to your own refinery operation. Taylor is today cooperating with the country's leading engineers in designing and installing the most exact, efficient, economical, money-saving control systems available.

Get all the facts about Taylor Service and Taylor's proved systems from a Taylor Representative, or direct from Taylor Instrument Companies, Rochester, N. Y. Plant also in Toronto, Canada. Manufacturers in Great Britain—Short and Mason, Ltd., London, England.

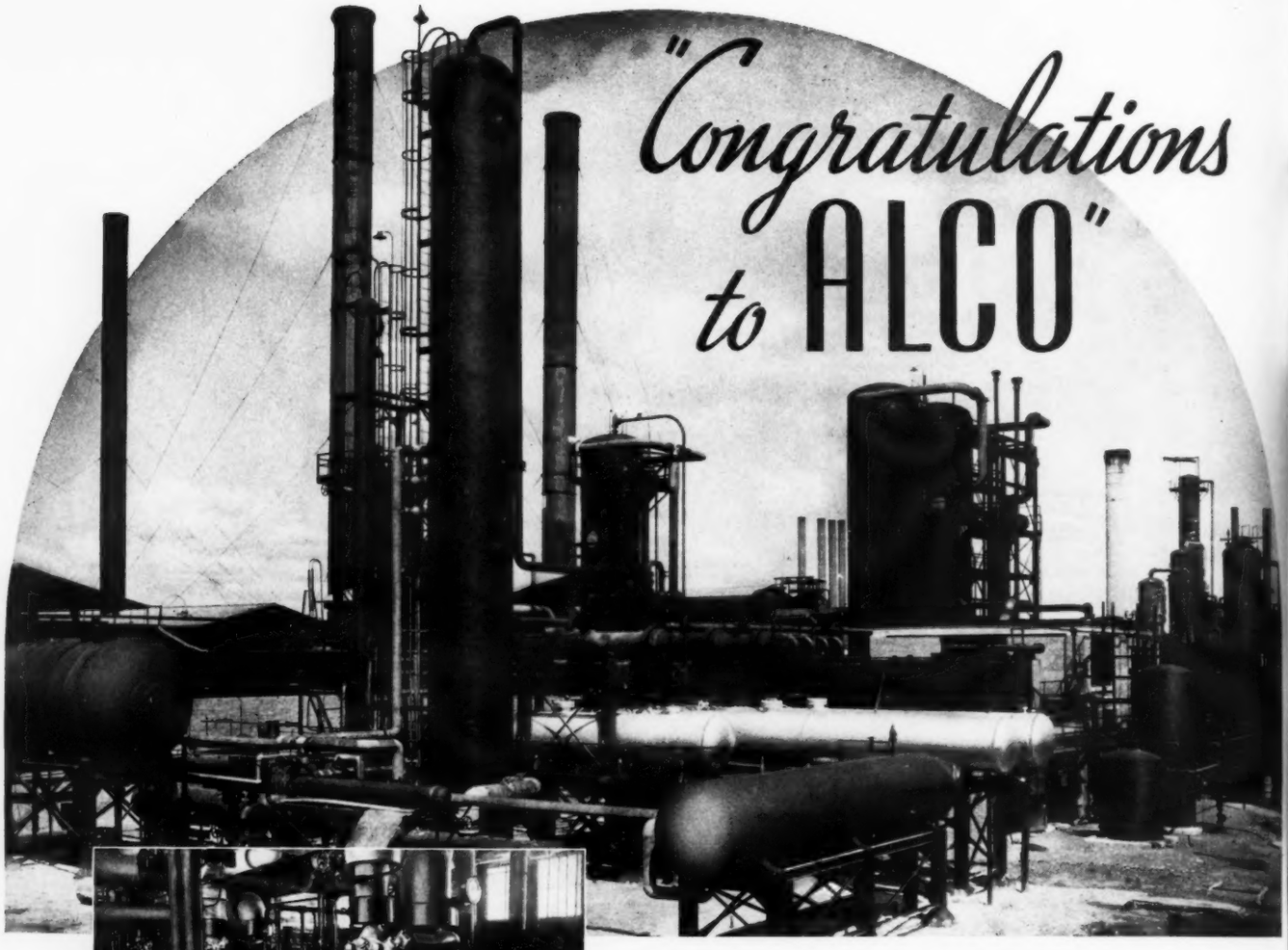
Taylor

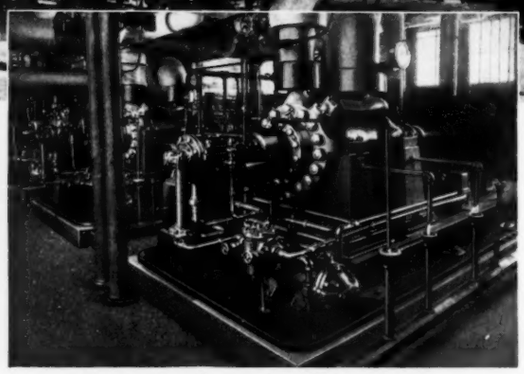
Indicating · Recording · Controlling

TEMPERATURE, PRESSURE, FLOW *and* **LEVEL INSTRUMENTS**



"Congratulations to ALCO"





Three five-stage Cameron Hot-Oil Charging Pumps

Type "XVG" Compressors

Cameron Pumps and Ingersoll-Rand Compressors have been installed in many refineries recently erected by Alco Products, Inc.

The widespread endorsement of Cameron charging pumps is the result of their excellent performance records over many thousands of hours of continuous operation without the usual long delays and high costs needed for repairs and dismantling. They can always be relied upon to maintain high efficiency and full capacity.

The "XVG" has proven to be the solution to all problems calling for the use of gas-engine-driven compressors in the petroleum industry, regardless of the type of service.

Ingersoll-Rand builds compressors in over 1000 different sizes and types of drive.

Other I-R products for refinery service are vacuum pumps, condensers, ejectors, Diesel engines and a complete line of pneumatic tools. Our engineers are experienced in refinery problems. They will be glad to work with you in selecting the equipment best suited to your requirements.

We are grateful for having been permitted to participate in the progress that has taken place in recent years in the refinery industry.

562-14

Ingersoll-Rand

11 BROADWAY, NEW YORK CITY

Branch Offices in Principal Cities the World Over

ALL UNDER THE SAME MANAGEMENT

There is no division of responsibility in the manufacture of TIMKEN Refinery Tubes. Quality control is entirely in the hands of the company's technical men—from the making of the steel to the finished product.

The importance and advantage of this to the tube user is apparent. It means better tubes. And it places full responsibility for your satisfaction in one place.

It will pay you to let us figure on your requirements in alloy or carbon steel tubes for any operating condition in stills, heat exchangers, condensers or other refinery equipment.

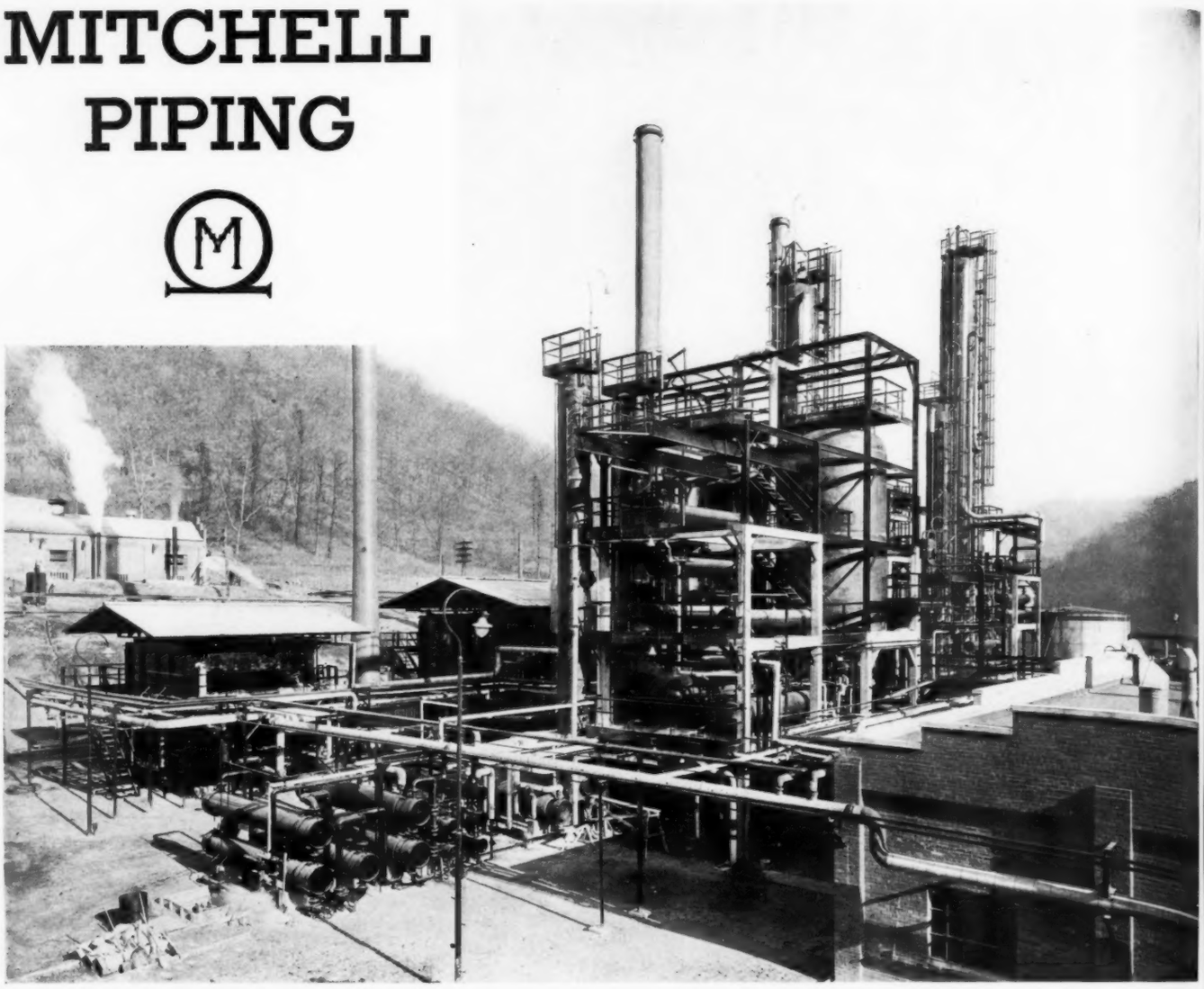
TIMKEN STEEL AND TUBE DIVISION
THE TIMKEN ROLLER BEARING COMPANY, CANTON, OHIO

8 Budd-built Zephyrs are now rolling on TIMKEN Bearings.
Glide—as you ride a Timken-equipped Train

Manufacturers of Timken Tapered Roller Bearings for automobiles, motor trucks, railroad cars and locomotives and all kinds of industrial machinery; Timken Alloy Steels and Carbon and Alloy Seamless Tubing; Timken Rock Bits; and Timken Fuel Injection Equipment.

TIMKEN
SEAMLESS STEEL TUBES

MITCHELL PIPING



used by

ALCO PRODUCTS

for

PURE OILS
CABIN CREEK PLANT

FABRICATORS and ERECTORS
of PIPING for all

Pressures, Temperatures
and Services

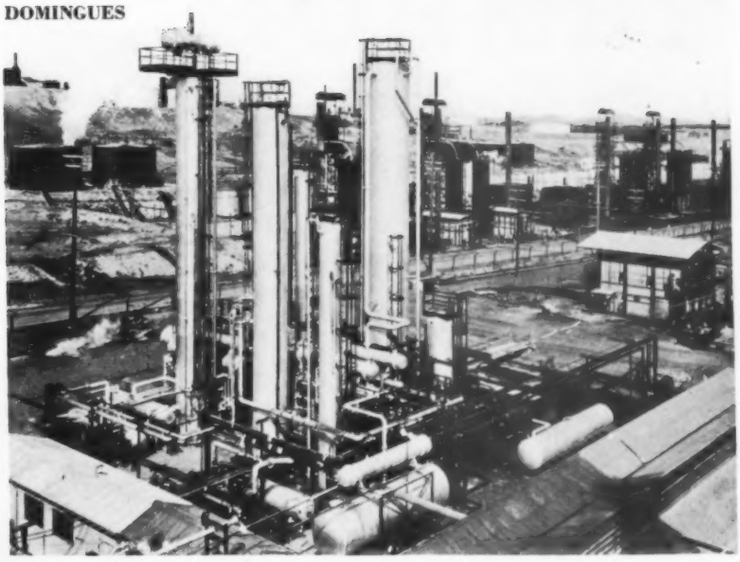
Specialists in Fabrication of
All Alloy Piping

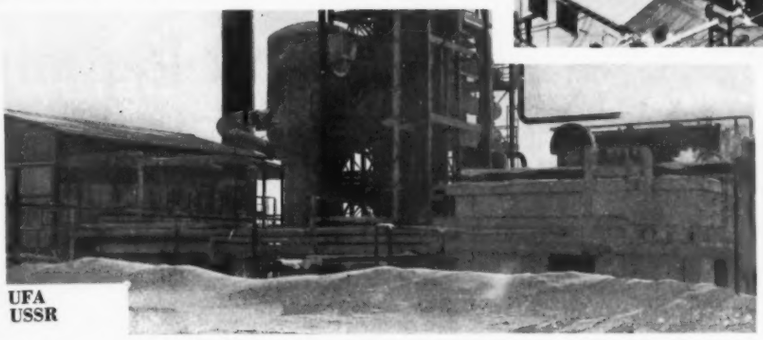
WELDING procedure and quality
to meet all insurance requirements

W. K. MITCHELL & CO., INC.
2940 ELLSWORTH ST., PHILADELPHIA, PENN.

MARTINEZ

DOMINGUES





UFA
USSR

GLOBE-TROTTING TRANSIT PUMPS

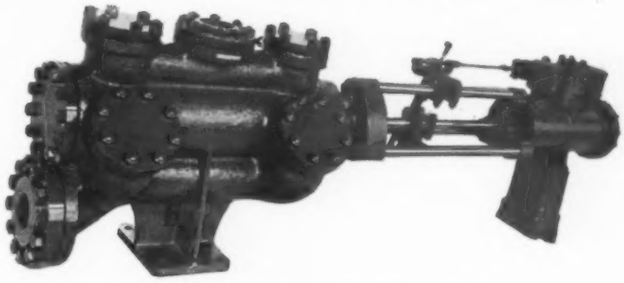
Fill every refinery need for severe conditions the world over

(Left) TRANSIT 3½ x 12" Horizontal Duplex Power Pump with forged steel liquid cylinders and totally enclosed splash lubricated power end. Dirt and dust sealed out, lubricating oil sealed in. Equipped with heavy duty, self-aligning roller bearings on both gear and pinion shafts. Capacity 104 gallons per minute of hot oil (850°F.) against 1500 lb. working pressure.

Water cooled stuffing boxes and plungers. Liquid cylinders supported along center line of bore by water cooled saddles. This patented arrangement permits the cylinders to expand in all directions with no change in alignment.

Right) TRANSIT 8 x 8 x 18" Horizontal Single, Close Clearance "ACE" type. High efficiency pumps for handling gasoline, butane, propane, and other highly volatile liquids. Clearances are reduced to a minimum by locating the suction and discharge valves close to the cylinder bore and using a piston designed to fill the piston clearances.

All valve seats are in a horizontal position, the valves themselves operating vertically. This insures an even distribution of wear and perfect seating—a feature not found in many makes of pumps of this type.



NATIONAL TRANSIT PUMP AND MACHINE CO.

OIL CITY, PENNSYLVANIA

NEW YORK • PHILADELPHIA • CHICAGO • CLEVELAND • PITTSBURGH • LOS ANGELES • HOUSTON • TULSA

Frick-Reid Supply Corporation
108 N. Trenton Ave.
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The Lang Company
267 West First South St.
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Pratt-Gilbert Company
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Arizona

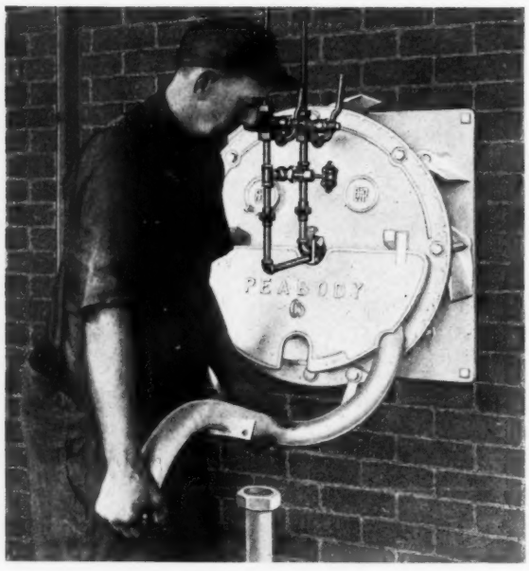
Reeves & Skinner Machinery Co.
2211 Olive Street
St. Louis, Missouri

Standard Supply and Hardware Company
822-838 Tchoupitoulas St., New Orleans, Louisiana

TRANSIT Pump & Engine Co.
2261 East 15th St.
Los Angeles, California

Eugene V. Winter Co.
320 Market St.
San Francisco, California

PEABODY BURNERS



Type "MU" Air Register with Gas and Oil Burners - Gas Ring Readily Removed and Replaced while Burner is Firing Oil.

GAS and OIL

To meet all Refinery operating conditions

Easy to Install
Simple to Operate
Inexpensive to Maintain

WE are justly proud of the record PEABODY BURNERS have established for themselves in the oil industry. Many of the new Refining and Steam Generating Units throughout the world are being fired with PEABODY BURNERS which are made in a full range of sizes and types. Air registers can be supplied for either Forced Draft or Natural Draft operation, and Liquid Fuel Atomizers can be of the Steam, Straight Mechanical or Wide Range Mechanical Type.

A few refineries where PEABODY BURNERS are firing ALCO built Units.

Ufa in U. S. S. R.
Pure Oil Co., Cabin Creek, W. Va.
Lago Petroleum Co., Aruba, D. W. I.
Atlas Pipe Line Co., Shreveport, La.
Anglo-Mexican Oil Co., Tampico, Mexico.
Socony-Vacuum Oil Co., Paulsboro, N. J.
Anglo-Iranian Oil Co., Ltd., Abadan, Iran
Tide Water Associated Oil Co., Avon, Calif.
Anglo-American Oil Co., Ltd., Ellesmere Port, England

Peabody Type "M" Air Register

There are PEABODY BURNERS firing heaters in practically every important Refinery throughout the world.

PEABODY ENGINEERING CORP.
580 FIFTH AVENUE
NEW YORK, N.Y.

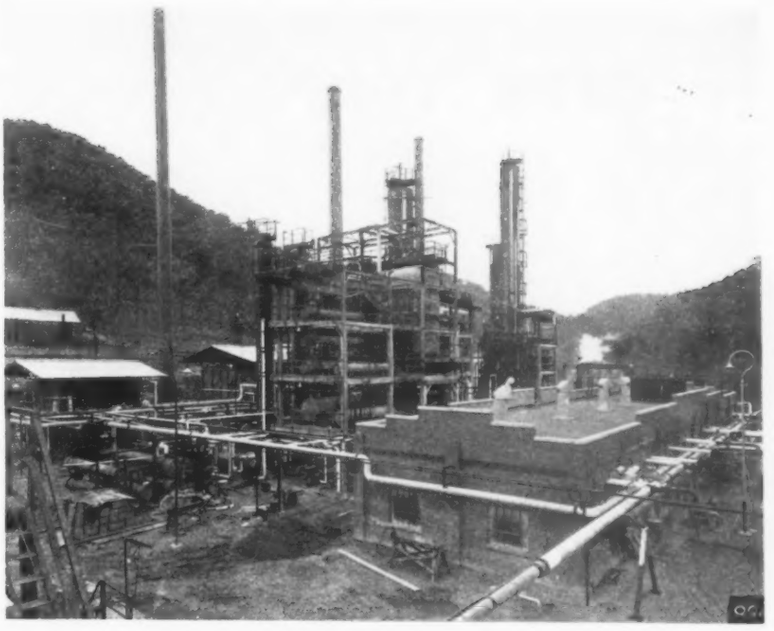
PEABODY LIMITED
4 CLEMENTS INN
LONDON, W.C. 2, ENGLAND

CATAWISSA

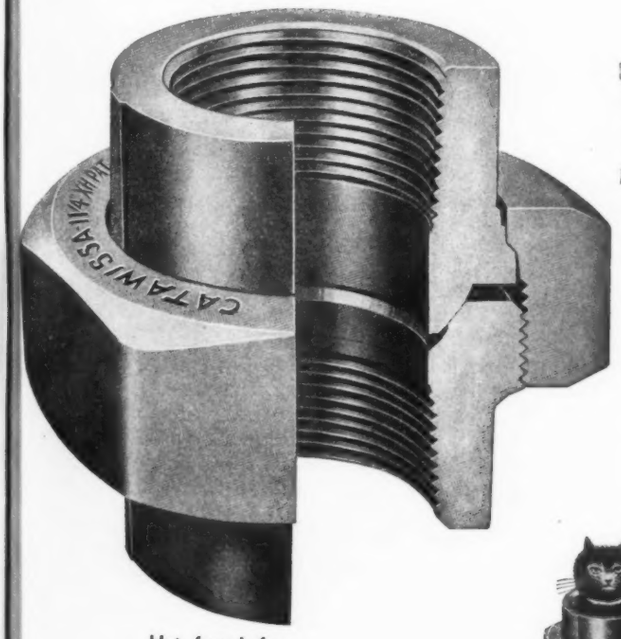
shares in the ALCO *record of achievement . . .*

CATAWISSA UNIONS are giving efficient service under Catawissa Guarantee in Alco plants throughout the world.

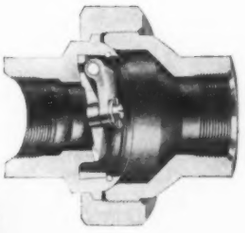
Catawissa Unions are used by leading oil refiners and refinery builders who know that guaranteed safety and performance are the paramount objectives in the selection of such equipment.



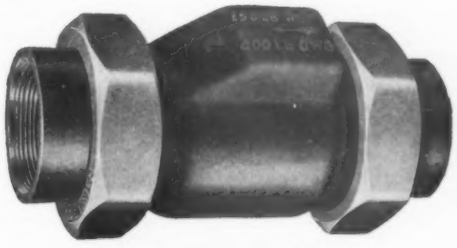
CATAWISSA UNIONS *and Catawissa Check Valves are giving guaranteed service in Alco plants.*



Hot forged from solid steel bars. Cold working pressure to 6000 lbs.



The Catawissa NEW FORGED STEEL check valve incorporates stainless steel working parts, is rated up to 600 lbs. steam and 1,500 lbs. oil, water or gas; the Catawissa new forged steel check valve will withstand pressures greatly in excess of these ratings. Safety and performance guaranteed.



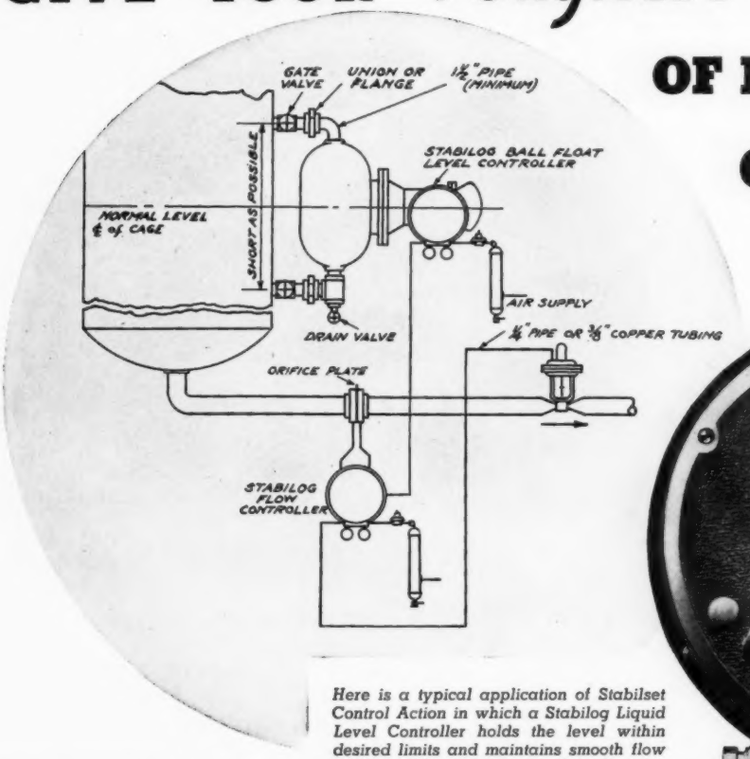
HORIZONTAL or VERTICAL

THE CENTRAL FORGING COMPANY

Manufacturers of "CATAWISSA" Forged Steel Unions and Valves

CATAWISSA, PA.

GIVE YOUR *Toughest Problems* OF LIQUID LEVEL CONTROL . . .



Here is a typical application of Stabilset Control Action in which a Stabilog Liquid Level Controller holds the level within desired limits and maintains smooth flow by setting the control point of the Stabilog Flow Controller.

TO THE STABILSET SYSTEM!

ITS PERFORMANCE IS PROVED!

Surges in a process . . . variations in steam supply to a pump . . . and other causes of like nature change the pressure drop across a controlled valve. This makes it impossible to secure averaging level control with a level control alone to handle such conditions. But, Stabilset Control System has proved its ability to make the toughest toe the mark.

A Stabilog Flow Controller, equipped with a Stabilset air setting mechanism, has its set point varied by an averaging type Stabilog Level Controller. The Flow Controller can master the surges and the Level Controller can produce averaging effects with respect to liquid level. That is Liquid Level Control by the Stabilset System. It permits . . . in fact, it forces . . . surge action within the vessel, and gives smooth control of outflow.

Write for Bulletin No. 210. It illustrates and describes Stabilset and two other types of Stabilog Liquid Level Control Action in detail. The Foxboro Company, 90 Neponset Avenue, Foxboro, Mass., U. S. A. Branch offices in 25 principal cities.

FOXBORO
REG. U. S. PAT. OFF.

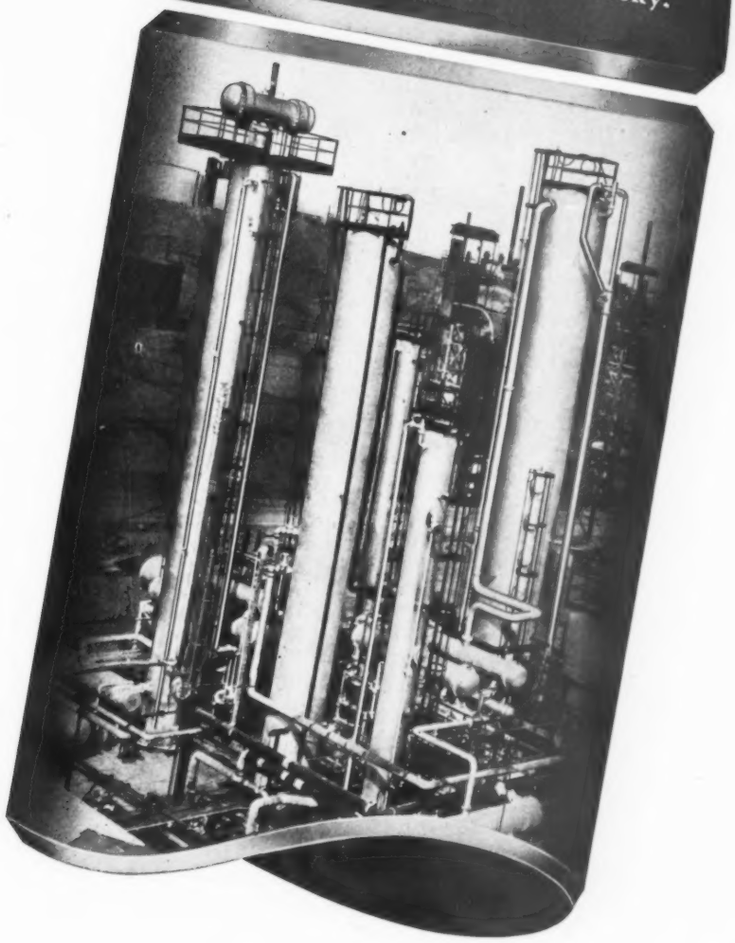
Certified STABILOG LIQUID LEVEL CONTROL
RESPONSE · ACCURACY

For *More Dependable Piping*

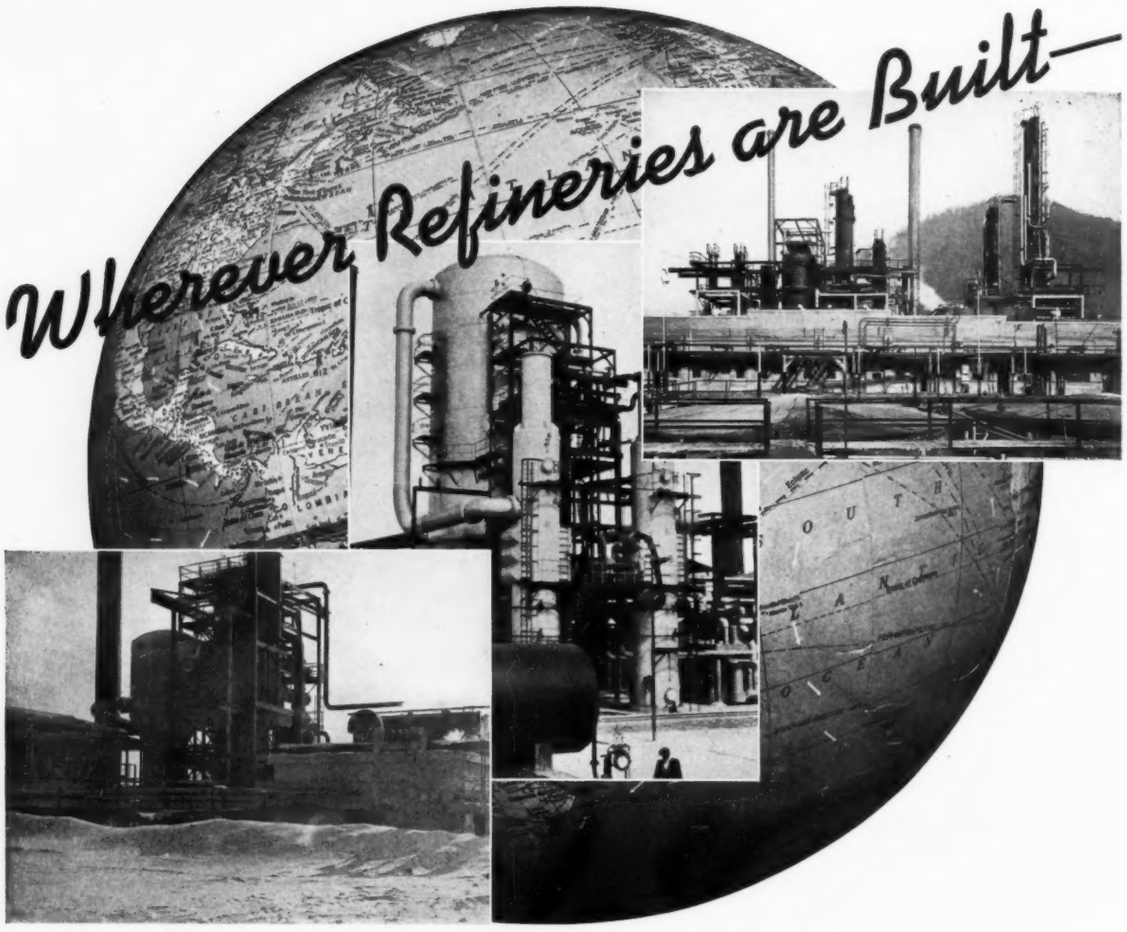
ALCO Engineers *Weld and Use*

TUBE-TURNS*

YEARS before any other fitting for welding had even appeared on the market, Tube-Turns were doing big jobs in the oil industry. Today Tube-Turns are still the first choice, and for exactly the same reasons as always—utter uniformity, complete dependability, under any kind of service to which the oil industry can subject them. . . . Alco Products use Tube-Turns—have used them for years in their most important jobs throughout the world. Isn't it safe to assume that Tube-Turns are the *right fittings* for your work too? . . . The complete Tube-Turn line of seamless fittings for pipe-welding and forged steel flanges in all series, types and sizes is illustrated and described in Catalog No. 107. Write for your copy today. . . . Tube-Turns, Incorporated, Louisville, Kentucky.



*The word "Tube-Turn" is NOT a necessary general trade name for welding fittings. It is the registered trade-mark for the products made by Tube-Turns, Incorporated, under their patents.



All over the world, wherever refineries are built Masoneilan Control Equipment is helping produce better, more profitable petroleum products.

This universal acceptance of Masoneilan equipment is based on merit alone — on correctness of design by engineers who know refining problems; on painstaking construction from the most suitable high quality materials; on Masoneilan insistence that performance standards be maintained.

MASONEILAN

The fact that many refineries designed and built by Alco Products Company — from Russia to the Argentine—include Masoneilan equipment is further evidence that refinery engineers recognize the Masoneilan trademark as a symbol of quality in design, construction and performance.

MASON-NEILAN REGULATOR COMPANY, 1192 ADAMS STREET, BOSTON, MASS., U. S. A.

New York Philadelphia Pittsburgh Chicago St. Louis Tulsa Houston Los Angeles

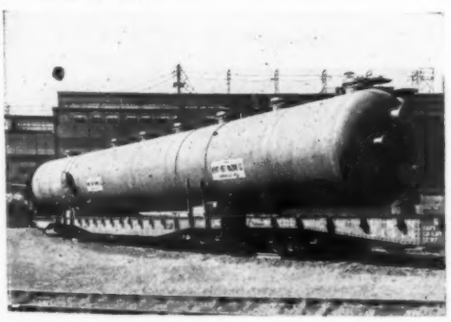
Vogt

PRODUCTS FOR OIL REFINERIES

Drop Forged Steel Valves and Fittings are forged from carbon steel billets or stainless steel if desired. They are unexcelled for high pressures, high temperatures, and resistance to corrosion and erosion.

Heat Exchangers for high pressure or vacuum service, with fixed or removable tube bundles and baffles, are of cast or welded all steel construction as desired. Special consideration is given to the selection of materials for handling corrosive fluids.

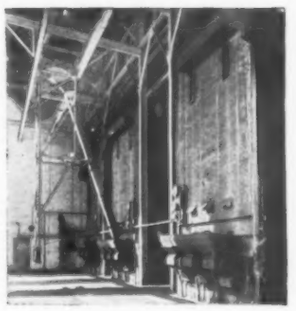
Fusion welded pressure vessels for every pressure and temperature complying with the A.S.M.E. Code.



THE worlds leading oil refineries specify Vogt products because of their distinctive features of design and construction for maximum efficiency and economy of operation.

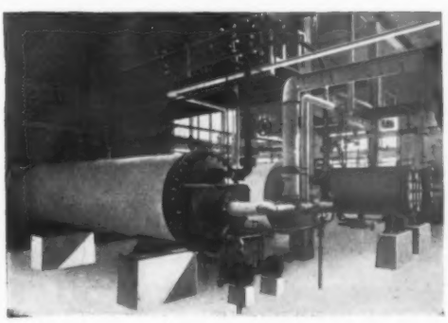
In addition to the products shown here, we manufacture Continuous Rotary Filters, Break Down Filter Presses, Oil Chilling Machines, Ammonia Condensers, Brine Coolers, etc., as well as special equipment which we build to order upon receipt of information.

Descriptive literature covering all Vogt products may be had upon request.



Water Tube Boilers, in bent tube, sectional header or box header types, for any fuel.

HENRY VOGT MACHINE CO. Inc.
LOUISVILLE, KENTUCKY
CABLE ADDRESS—VOGT
NEW YORK PHILADELPHIA CLEVELAND CHICAGO
CINCINNATI KANSAS CITY DALLAS



Complete Absorption and Compression Refrigerating Systems for every refrigerating service and with booster units may be arranged for temperatures as low as minus sixty to minus seventy degrees Fahrenheit.

THE *Complete* PYROMETER

The completeness with which this Micromax displays temperature readings is typical of the completeness with which it performs every pyrometer function. It can operate any control mechanism; any alarm. It provides combinations of indication, record, alarm and control that cannot be had in other models. It performs reliably in control room, foreman's office or isolated control station.

From earlier L&N pyrometers it inherits reliability, sensitivity and accuracy, qualities to which it adds visibility, versatility and accessibility. Crystallizing the values of a quarter-century of pioneering progress, it is simple and complete—capable of the greatest return per dollar of pyrometer investment.

JN33-702(5)

LEEDS & NORTHRUP COMPANY, 4945 STENTON AVE., PHILA., PA.

LEEDS & NORTHRUP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

FOR THE VITAL ARTERIES OF REFINING . . .

THE GLOBE FOREN PROCESS PROVIDES PLUS FEATURES IN SEAMLESS STEEL TUBING

The FOREN PROCESS, while new in principle, is a proven, sensational success in the production of seamless steel tubes . . . tubes far superior to those produced by other methods.

The improved finish is an important advantage. For example, it often permits the use of a tube with a lighter wall and less weight of metal to obtain the desired strength. Again, it eliminates the chance that scale or other solid matter may be deposited and become lodged. This feature is particularly important in condenser and heat exchanger tubes.

Globe Engineers will gladly tell you more about the FOREN PROCESS and its particular advantages for oil refinery applications.

Upper Picture — Pure Oil Company's plant at Cabin Creek, West Virginia: Globe FOREN PROCESS tubes installed at this plant by Alco Products, Inc.

•

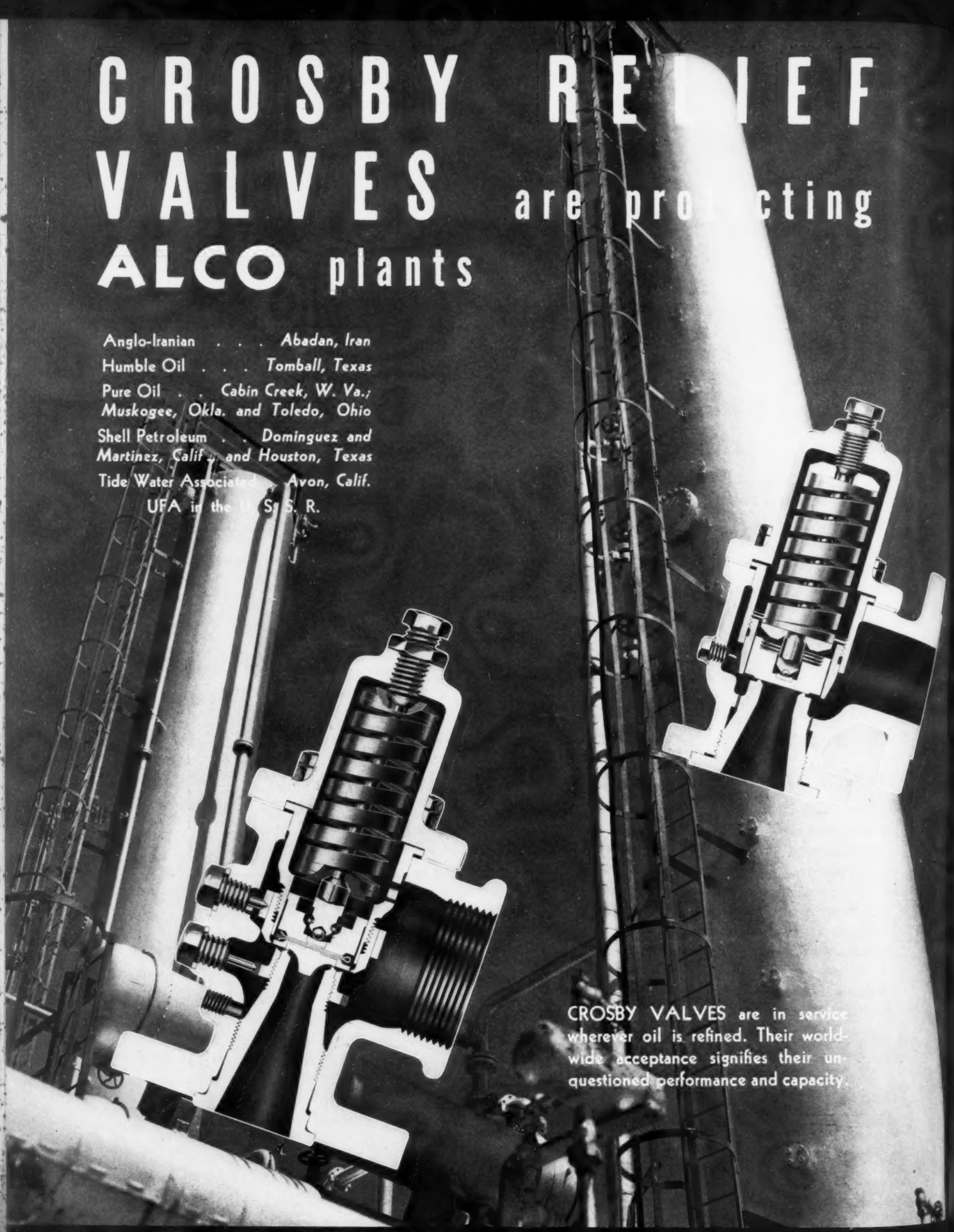
Lower Picture—Partial view of the unique FOREN PROCESS mill at Milwaukee

GLOBE STEEL TUBES CO.
4009 W. Burnham St. Milwaukee, Wis.

GLOBE STEEL TUBES
Seamless for Safety

CROSBY RELIEF VALVES are protecting ALCO plants

Anglo-Iranian . . . *Abadan, Iran*
Humble Oil . . . *Tomball, Texas*
Pure Oil . . . *Cabin Creek, W. Va.; Muskogee, Okla. and Toledo, Ohio*
Shell Petroleum . . . *Dominguez and Martinez, Calif., and Houston, Texas*
Tide Water Associated . . . *Avon, Calif.*
UFA in the U. S. S. R.

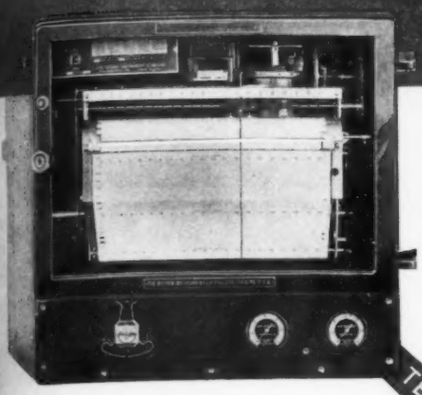


CROSBY VALVES are in service wherever oil is refined. Their world-wide acceptance signifies their unquestioned performance and capacity.

CROSBY STEAM GAGE AND VALVE CO.

BOSTON · NEW YORK · CHICAGO · LOS ANGELES

THE PROPER SOLUTION TO THESE CONTROL PROBLEMS IN OIL REFINING



AIR-o-LINE Potentiometer Controller combines in one instrument the measuring and recording precision of the potentiometer and the adaptability of the air operated controller with 1% to 150% throttling range and automatic reset. For temperatures—300°F. to plus 3400° F.

Leads to

TEMPERATURES

PRESSURES

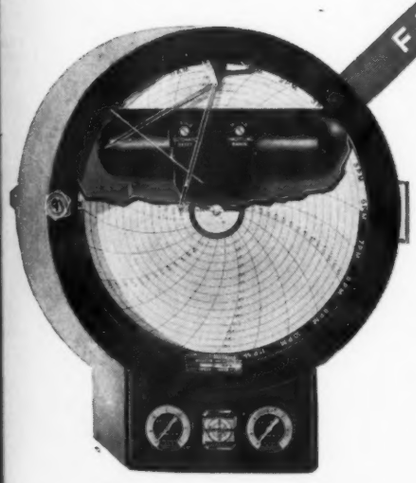
AIR-o-LINE pressure controllers with 1% to 150% throttling range and automatic reset are available for control of pressure within limits of 5" of water and 3000 pounds per square inch

BROWN

Air-O-Line

FLOWS

LIQUID LEVELS



AIR-o-LINE flow controllers are furnished as either electric or mechanical type flow meters with 1% to 150% throttling range and automatic reset. For working pressures up to 2500 lbs.

AIR-o-LINE liquid level controllers are furnished as either electric or mechanical type liquid level meters with 1% to 150% throttling range and automatic reset. For control of liquid levels from 20" of water to 100 feet of water.

Brown *AIR-o-LINE* insures accurate measurement and precise control of temperatures, pressures, flows, liquid levels in the operation of plants or units engaged in Distillation—Cracking—Vapor Recovery — Acid Treating — Polymerization — Hydrogenation — Residuum Treating—Solvent Treating—Dewaxing and Gasoline Absorption.

Brown *AIR-o-LINE* provides a means for tuning into your specific process requirements simply and quickly, without dismantling the controller or interrupting its control operation.

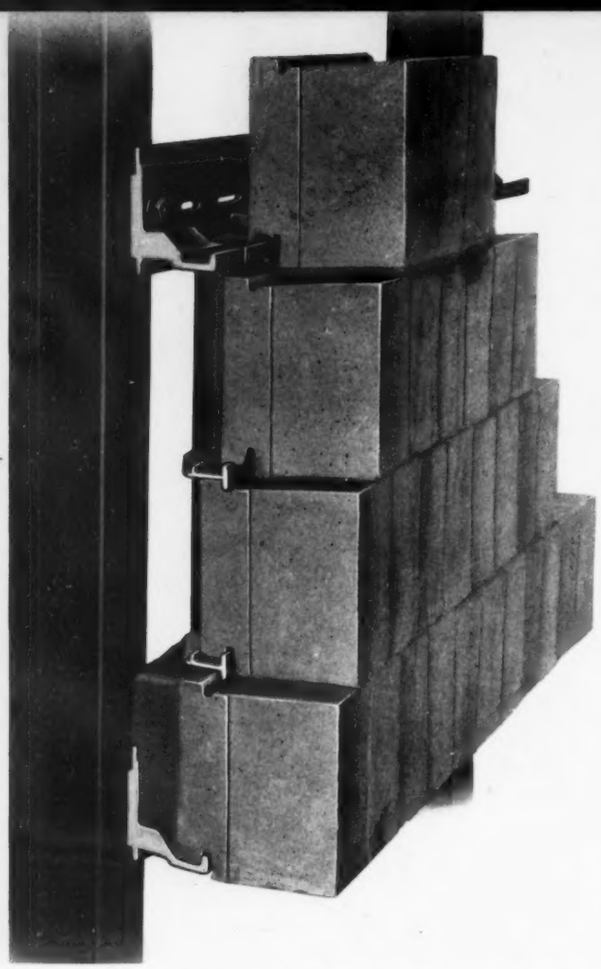
Operators are encouraged to secure "best possible" not just "good enough" control results, so apt to be present where adjustments are complicated and time-consuming.

Brown *AIR-o-LINE* is set with the same simplicity as dialing a radio. Once it is "tuned in" it becomes fully automatic. It not only controls the process within limits, but it "lines out" control at the exact desired control point, regardless of load or throughput changes, assuring you of a balanced operation—correct throughput, closer cuts—higher octanes and maximum yields at lowest cost.

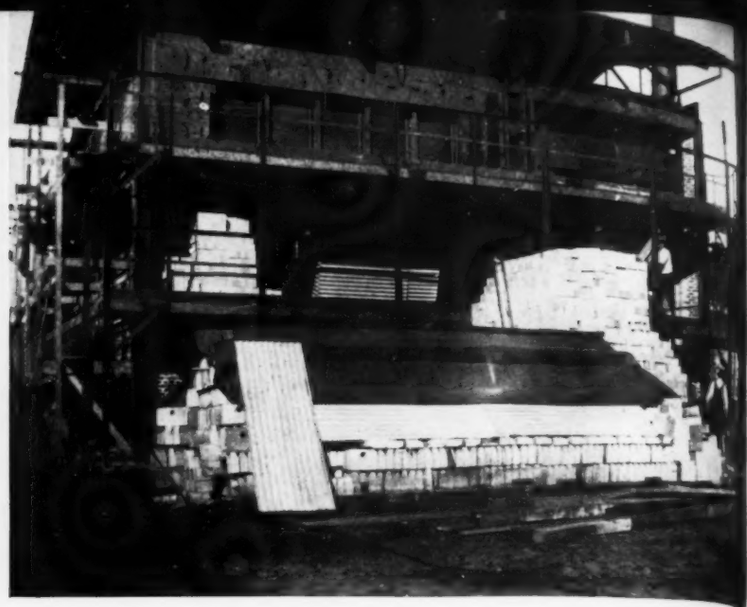
Brown *AIR-o-LINE* has everything you have wished for in air operated control—it "recognizes," "analyzes," and "corrects" for any departure from the exact control setting—without "cycling," "drifting," or "shifting" of the control point. Modernize your process control with this modern Air-Operated Controller. Write for Catalog No. 8902. THE BROWN INSTRUMENT COMPANY, *a division of Minneapolis-Honeywell Regulator Co.*, 4450 Wayne Avenue, Philadelphia, Pa. Offices in all principal cities. Toronto, Canada: 117 Peter Street—Amsterdam-C, Holland: Wijdesteeg 4—London, England: 70 St. Thomas' Street, S.E.1.

BROWN AIR OPERATED CONTROLLERS

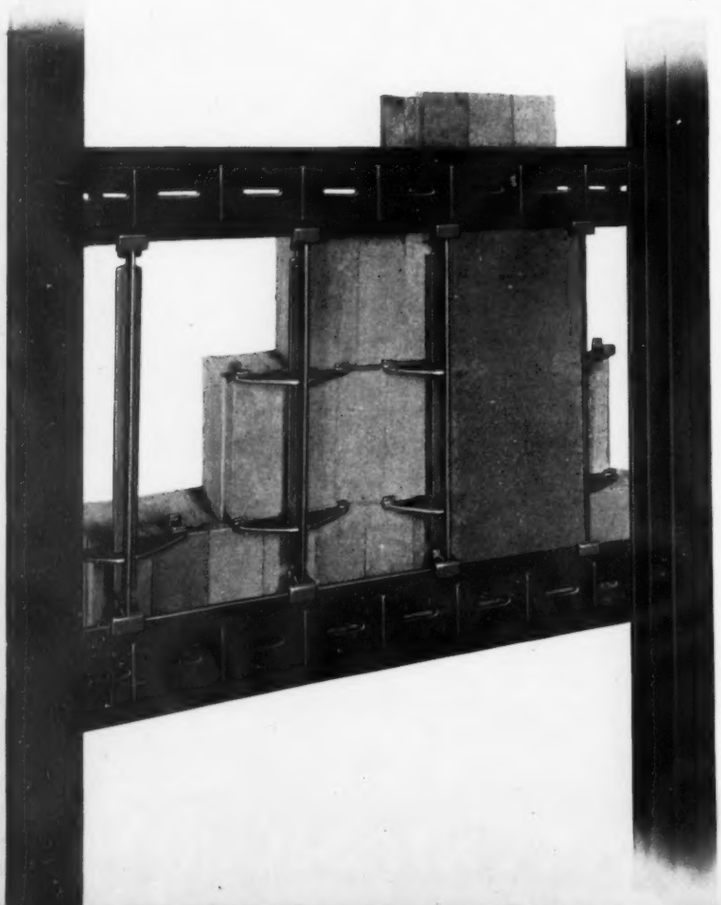
OUTSTANDING PERFORMANCE WITH SIMPLICITY



Front View—CHICO Type B Sectionally Supported Wall
Illustrating advantages as enumerated



Rear View—CHICO Type B Sectionally Supported Wall
Note part application of Insulation



The CHICO Type B Wall

Ideally Adapted to Oil Refinery Furnace Installations

Conforming with the basic progress in the design of modern sectionally supported walls, the CHICO type B wall incorporates advantages that have been proved by existing installations, as well as new ideas in anticipation of the requirements of the suspended wall of the future. Together with the CHICO Arch, there is thus provided a truly progressive development in suspended furnace construction.

The CHICO type B wall is especially adapted to oil refinery furnaces, because its flexible construction meets the specific requirements of furnaces of this type. A review of the following features clearly discloses the advantages of this modern design.

1. Simplicity. One tile shape for a standard section.
2. Flexibility. Castings and tile free to move to offset expansion and contraction.
3. Offset expansion joint the full thickness of the tile.
4. Tile surfaces offset to make refractory lining air and gas tight.
5. Repairs localized to all sections.
6. Can be installed or repaired from either inside or outside of furnace.
7. Maximum and uniform burning depth per given thickness of refractories.
8. Insulated to give utmost efficiency.
9. Minimum of supporting castings imbedded in refractories.
10. A suspended wall construction that pays for itself by virtue of its general efficiency.

CHICO suspended walls are of the air cooled or insulated type and, together with CHICO Arches, are available with standard, super or insulating refractories. We invite your inquiries for design and prices covering specific requirements.

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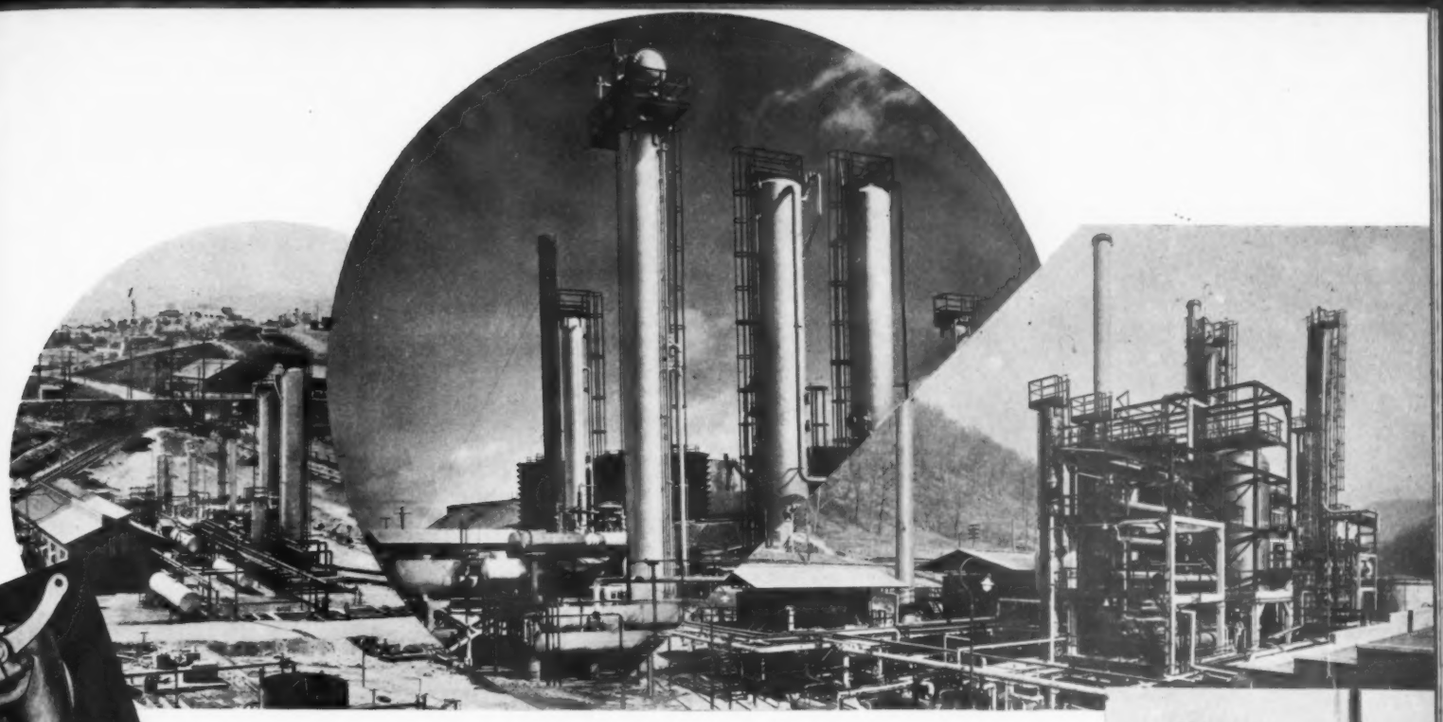
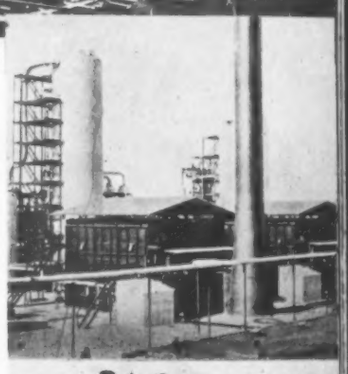
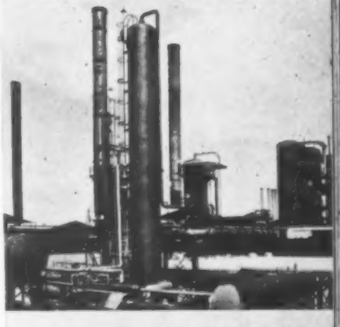
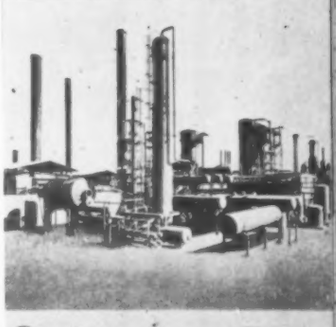
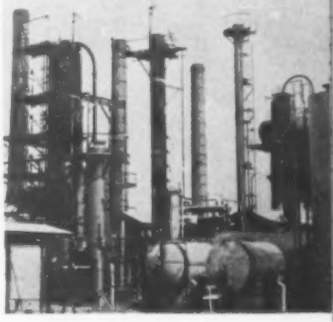


There's a Strahman Gage or Gage Valve for every refining process









It is only natural that such efficient equipment should be specified in ALCO built plants.

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In cracking, solvent extraction, dewaxing and hydrogenation plants, and wherever high temperatures and pressures are to be encountered Strahman-S Gages and Gage Valves are rendering super-service at pressures up to 4,400 lb. per sq. in. They are equally efficient when operating against extreme sub-zero temperatures. For hot climates Strahman makes a self-cooling gage assuring a true level reading of the liquids in tanks.

Strahman Super-S Gage Valves are outstanding because of their automatic, quick closing, ball check and the ease with which the gage glass can be cleaned without removing the entire gage assembly from the tank or tower. Furnished with either threaded or flanged tower connections.

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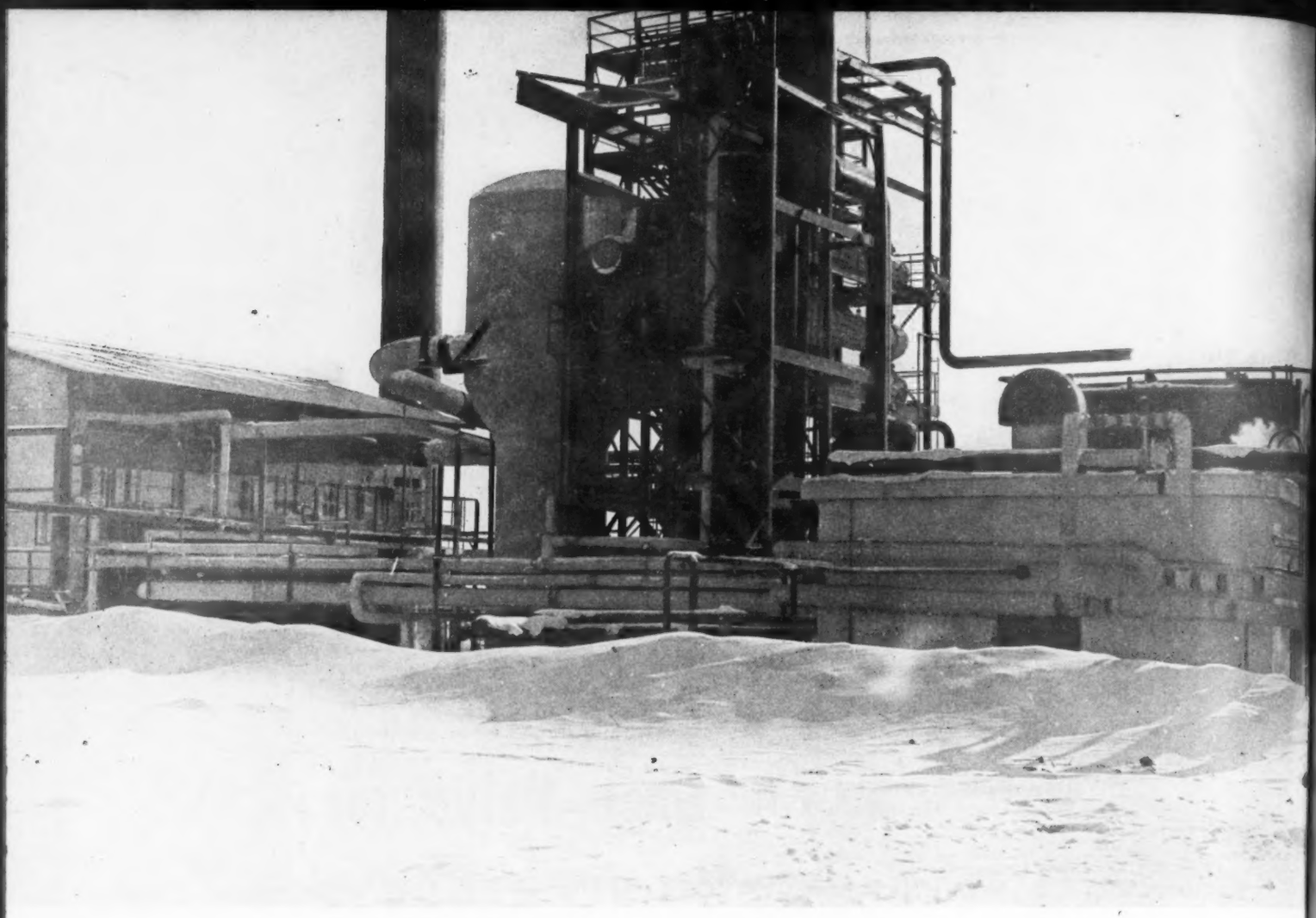

Pictured Above Is a Part of the UFA Refinery at Sterlitamak, Russia

This Refinery Was Built by Alco Products, Incorporated

•

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in the Distillation, Cracking
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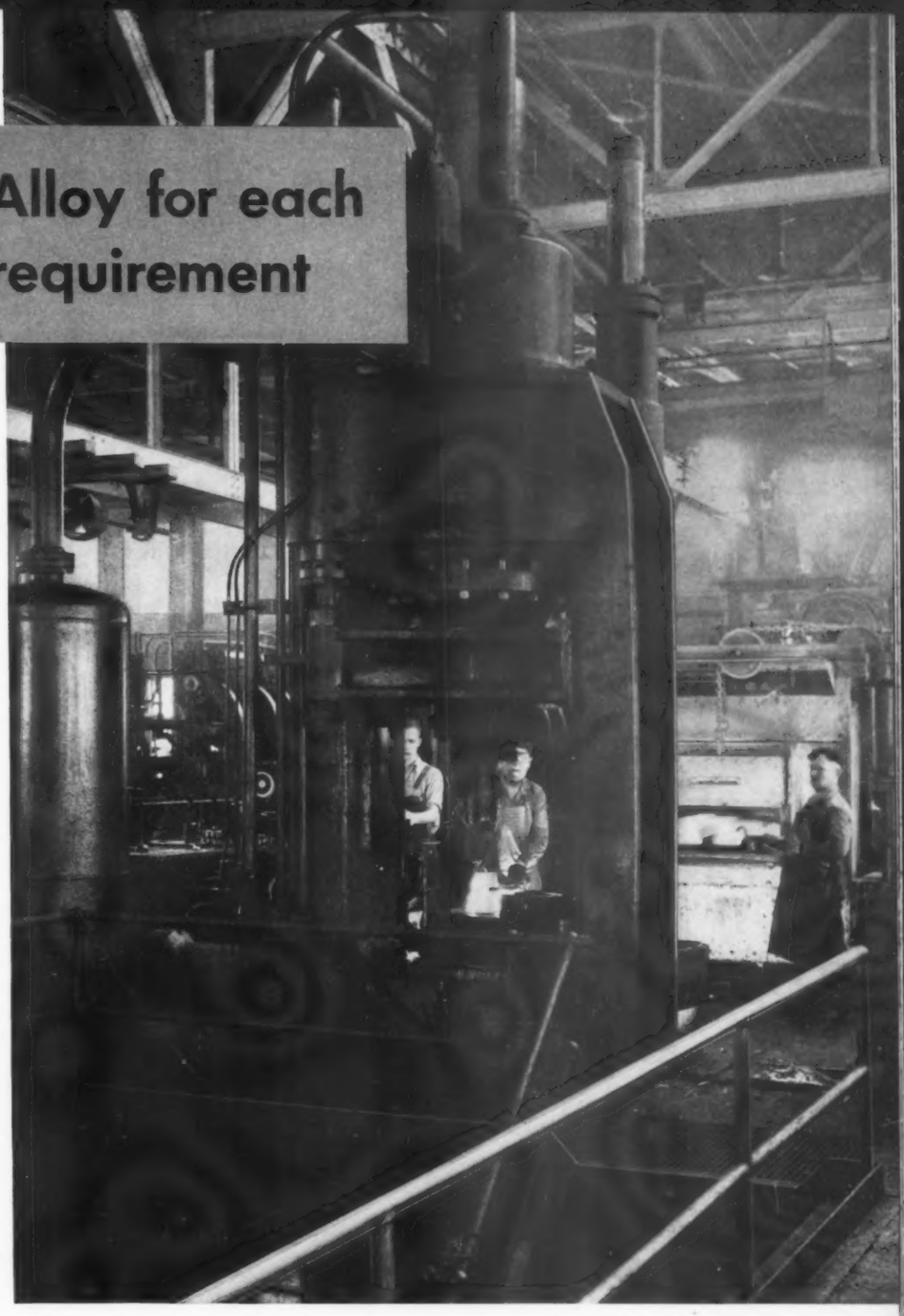

Water conditions, pressures, temperatures, and velocities all have a bearing on the selection of the most economical Condenser Tube alloy. After all factors have been taken into consideration, the alloy selected should most certainly be the one that will give the greatest service per dollar of cost.

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For complete information and data on all Anaconda Condenser Tube Alloys and various methods of manufacture, write for copy of Anaconda Publication B-2.

The list below shows the wide range of condenser tube alloys regularly furnished by The American Brass Company.

ANACONDA
from mine to consumer

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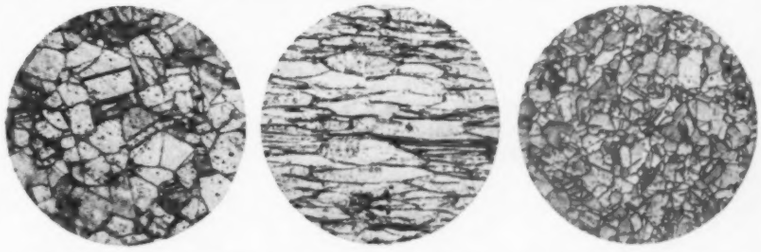
COMPOSITIONS OF ANACONDA CONDENSER TUBES

Alloy	*Copper %*	*Nickel %*	*Zinc %*	*Aluminum %*	*Tin %*
SUPER-NICKEL 701	70	30	0	0	0
CUPRO NICKEL 712	80	20	0	0	0
AMBRAC 850	75	20	5	0	0
AMBRALOY 927	76	0	22	2	0
ADMIRALTY ALLOY 422	70	0	29	0	1
"85" RED-BRASS	85	0	15	0	0
70-30 BRASS	70	0	30	0	0
MUNTZ METAL	60	0	40	0	0
COPPER, DEOXIDIZED 939	99.9	Phosphorus,	0.02%		
COPPER, ARSENICAL 945	99.7	Arsenic,	0.25%		

The above figures are approximate only



EXTRUDED—At this first stage a heavy-walled tube has been extruded from a pierced billet. Grain structure is coarse, but surfaces are smooth — free from scratches or other imperfections.

ROLLED—Cold rolling the extruded tube over a mandrel completely changes the grain structure throughout the entire cross section of the tube. Smooth inside surface is retained.

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ABOVE MICROGRAPHS SHOW MAGNIFICATIONS OF 150 DIAMETERS

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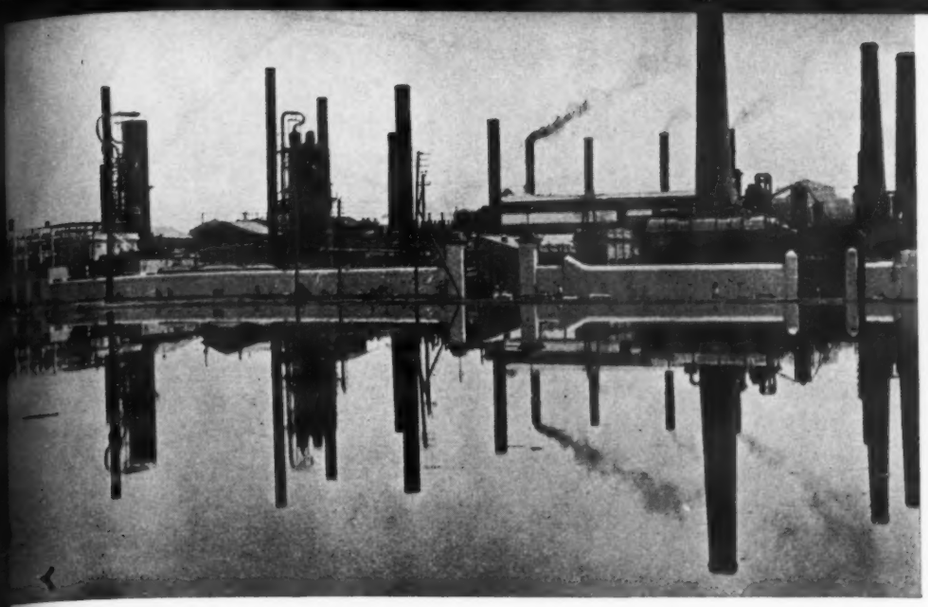


Pyatakov oil refinery—one of Baku's largest—reflected in the waters of the Caspian Sea.

© Sovfoto

Putting the finishing touches on a new cracking and reforming unit at Baku.

SOVIET REFINERY

Construction Enters Third Phase

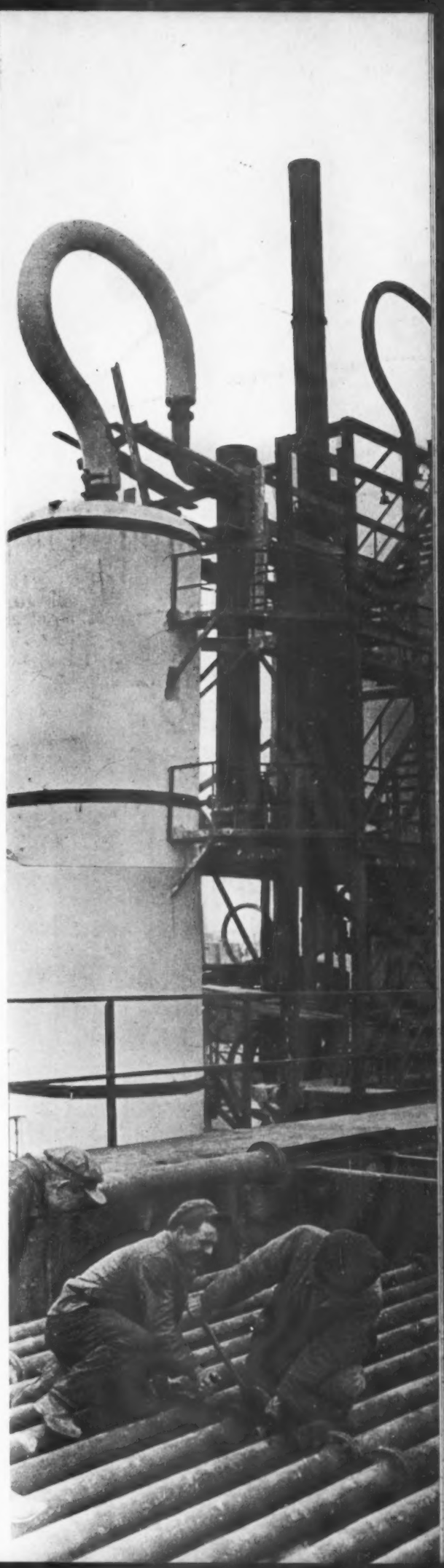
By J. Wegrin

Finding Themselves Possessed of A Few Obsolete Plants After the Revolution The Soviets Relied on Imported Plant and Technical Experience to Build Adequate Refining Facilities Until 1932 When Extensive Importation Was Stopped. Today Russia Again Finds It Necessary to Call on Outside Sources for Modern Processes, Efficient Design and Reliable Refinery Materials.

PRIOR to 1928 all reconstruction in the Russian refining industry consisted of domestic modernization of installations taken over by the Soviet government from private owners after the revolution, plus a small amount of German equipment. Large orders for refining equipment were placed in the United States, Britain and Germany during the period from 1928 to 1932. These purchases included atmospheric, atmospheric-vacuum and high vacuum plants from Graver, Foster Wheeler, Badger, Alco and Max Miller; cracking units from Vickers and Winkler Koch; and shell batteries and pipe stills from Pinch Borman Wilke.

This period of reconstruction and major new refinery building was almost completed in 1932, when it was decided to cease importations from abroad and to replace obsolescent equipment, with a few exceptions, with that of domestic design and construction. The Soviets considered that they had obtained sufficient technical assistance from other countries and that the new refineries already erected in Russia by overseas contractors would serve as models for further units desired.

During subsequent years Russian refinery engineers used these plants as guides to further construction, and in some cases the original types were modified. An example of such modification is that of



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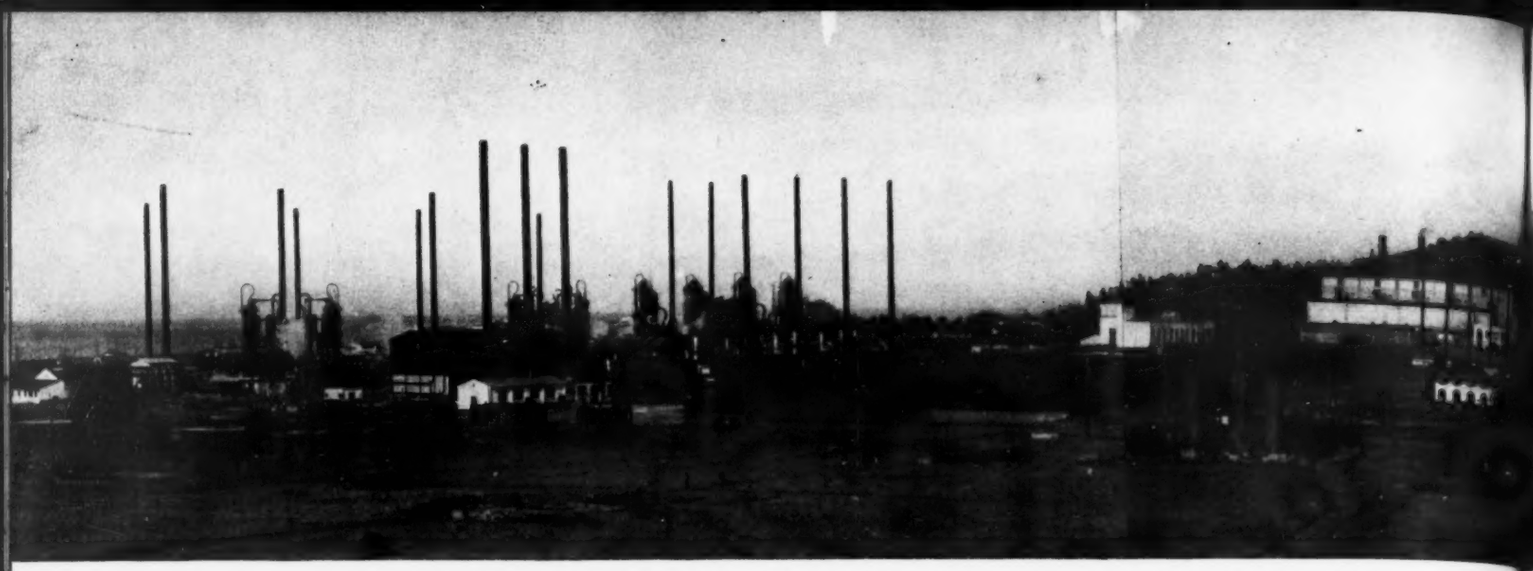

Above, general view of the Batoum refinery; below, Soviet cracking plant at Baku, showing the rectification columns.

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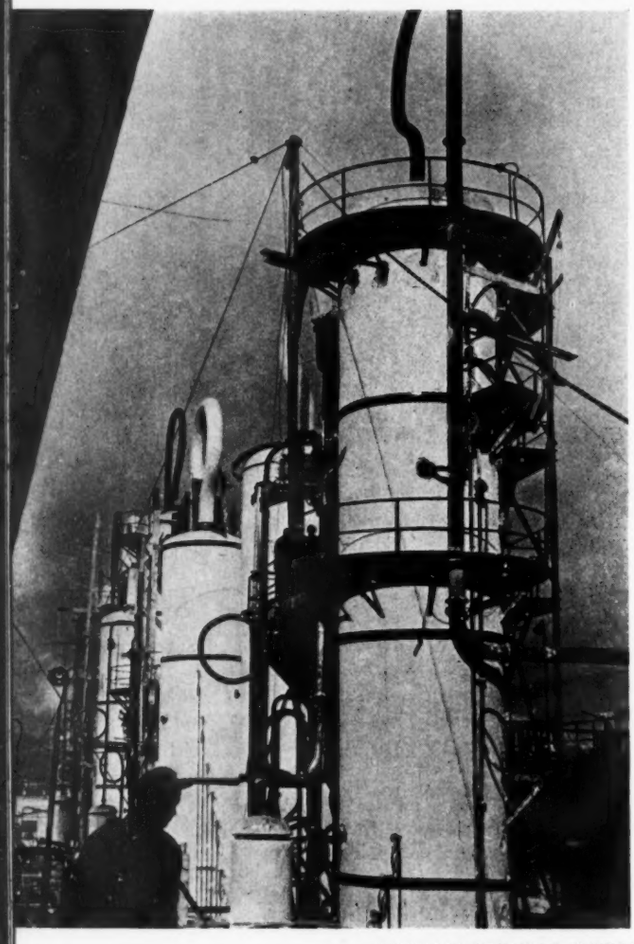

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Winkler Koch cracking units revised to two furnace cracking operations. Attempts were likewise made to design domestically a vapor phase cracking installation, while construction of liquid-vapor phase cracking plants was undertaken.

By 1935 the Soviet oil industry listed among its refining facilities 36 shell still batteries, 30 pipe stills, 32 lubricating oil installations, and 34 cracking units, capable of processing an aggregate total of 853,250 bbl. of both raw and topped crude daily.

The Second Piatiletka provided for the installation during the five years of 46 pipe stills and 93 cracking units, to be distributed over the country with a view of bringing refining nearer to the industrial points of consumption. No refinery construction was completed during 1933 and 1934, but during 1935 an appreciable amount of work was done. Four combination atmospheric-vacuum installations, with a total capacity of 117,000 bbl. of crude daily, were built at Baku. Three were of Alco design and one was a Badger unit for lubricating oil production. Four Soviet-designed Winkler Koch-type cracking units of 11,200 bbl. capacity were also erected at Baku. A skimming plant of domestic design and an Alco combination atmospheric-vacuum plant with 12,000 bbl. crude oil capacity were built at Ufa, while a similar unit of the same capacity was designed by Soviet engineers and erected at Orsk. Four cracking units, built to Soviet designs based on Winkler Koch plants, were installed at Grozni to treat a total of 14,000 bbl. daily and two similar units were constructed at Saratov with a total input of 7,000 bbl. per day. Some of these installations were not finished in time to come on stream during 1935, but were completed in 1936.

According to original plans very extensive refinery construction had been intended to take place during 1935, but compared with the schedule only a small proportion was actually undertaken. Crude oil production was not as great as anticipated, and the domestic machine shops were not in a position to cope with requirements. The new refineries would have necessitated more than 100,000 tons of equipment and 800,000 ft. of pipe.

Likewise, great plans were laid for 1936, but much of the construction had to be held over for completion in 1937. Construction during 1936-1937 included two Soviet-designed atmospheric-vacuum installations, with an annual throughput of 14,000,000 bbl., and four Soviet-designed cracking units, capable of treating an input of 3,000,000 bbl. per annum, at Baku. Four two furnace cracking units of Russian design were erected at Grozni. An atmospheric-vacuum plant, annual capacity 3,500,000 bbl., and two cracking plants

RUSSIAN REFINING INSTALLATIONS IN 1935

Location	Shell Stills	Pipe Stills	Lube Oil Plants	Cracking Units	Total Installations	Daily Capacity
Baku	16	12	16	4	48	330,000 bbl.
Batoum	1	4	1	6	12	96,000 bbl.
Grozni	7	9	3	14	33	300,000 bbl.
Tuapse	1	2	—	2	5	52,500 bbl.
Krasnodar	2	1	—	—	3	22,000 bbl.
Gorki-Konstantinovka	4	1	1	1	7	12,500 bbl.
Yaroslavl	—	—	1	—	1	5,000 bbl.
Santo Chimion	2	—	—	—	2	3,500 bbl.
Khabarovsk	—	—	—	1	1	4,000 bbl.
Saratov	—	—	—	6	6	21,000 bbl.
Moscow	1	—	—	—	1	1,250 bbl.
Odessa	1	—	—	—	1	1,250 bbl.
Leningrad	—	1	—	—	1	3,000 bbl.
Varinsk	1	—	—	—	1	1,250 bbl.
Orsk	—	—	—	—	—	———
Ufa	—	—	—	—	—	———
Berdiansk	—	—	—	—	—	———
Kherson	—	—	—	—	—	———
Totals	36	30	22	34	122	853,250 bbl.

RUSSIAN REFINING INSTALLATIONS IN 1937*

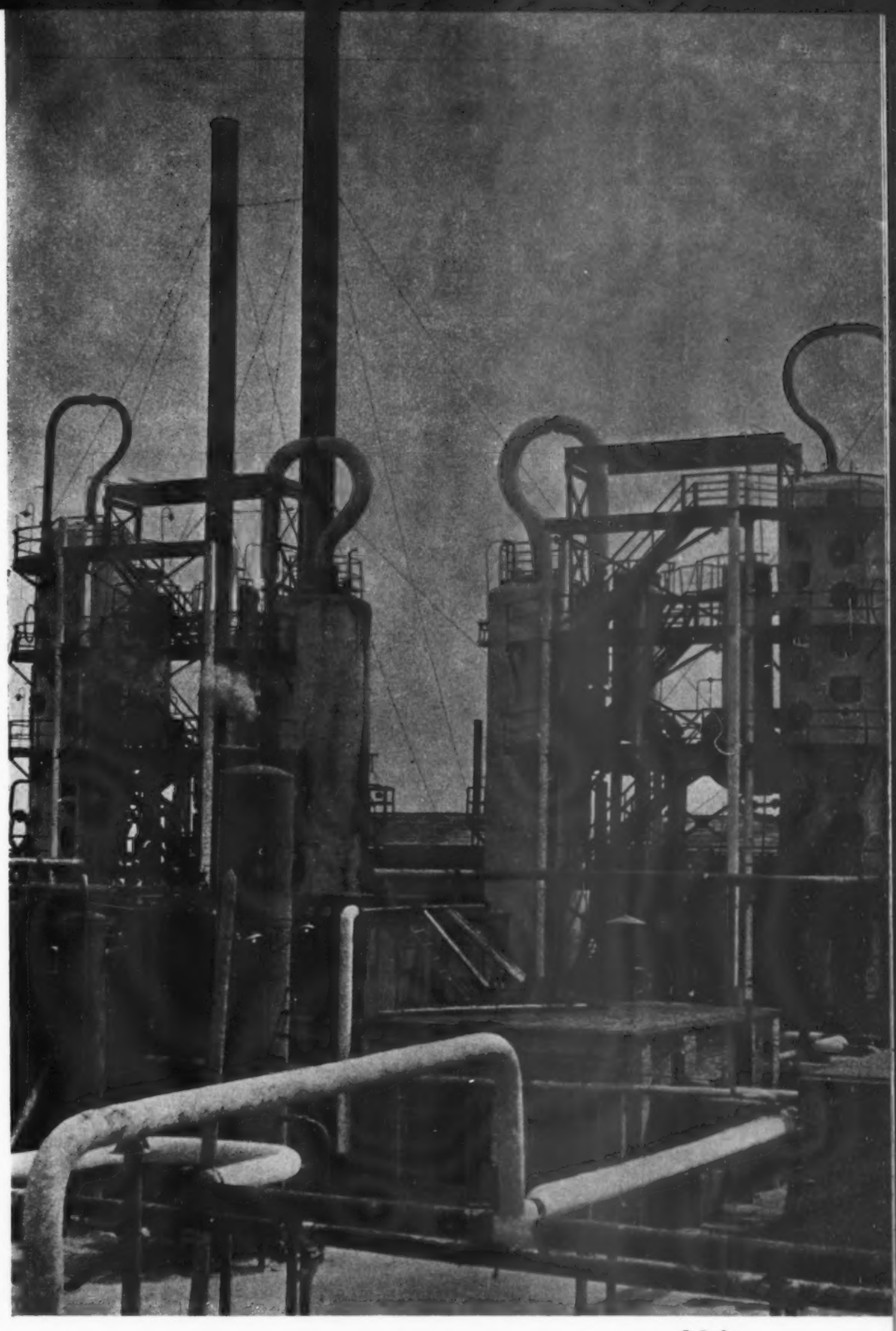
Shell Stills	Pipe Stills	Lube Oil Plants	Cracking Units	Total Installations	Daily Capacity
15	20	16	16	67	465,000 bbl.
1	4	1	6	12	96,000 bbl.
7	9	3	24	43	373,000 bbl.
1	2	—	2	5	52,000 bbl.
2	1	—	—	3	22,000 bbl.
4	1	1	1	7	12,700 bbl.
—	—	2	—	2	7,000 bbl.
2	—	—	—	2	3,500 bbl.
—	—	—	1	1	3,000 bbl.
—	—	—	10	10	38,000 bbl.
1	—	—	2	3	9,750 bbl.
1	—	—	1	2	5,800 bbl.
1	1	—	—	2	1,750 bbl.
1	—	—	—	1	5,700 bbl.
—	1	—	2	3	17,500 bbl.
—	2	—	—	2	12,000 bbl.
—	—	—	1	1	4,000 bbl.
—	—	—	1	1	4,000 bbl.
36	41	23	67	167	1,132,700 bbl.

*October.

© Sovfoto

2,100,000 bbl. capacity per annum, were constructed to domestic designs at Orsk. Two combination atmospheric-vacuum installations, each of 3,500,000 bbl. per year capacity, were built at Ufa—one to Alco designs while the other was a Soviet job. Two Soviet dual furnace cracking units were built at Saratov, having a total throughput of 3,500,000 bbl. yearly, and a similar installation was constructed at Moscow to treat 1,275,000 bbl. per annum. A cracking plant capable of treating 1,275,000 bbl. per year was erected at Berdiansk, and another of similar Soviet design and the same capacity was put up at Kherson. A two furnace asphalt cracking unit was constructed at Odessa, also to treat 1,275,000 bbl. yearly. Contracts made with the Univeral Oil Products for Dubbs plants are reported to include at the Soviets' disposal both technical assistance and working drawings. An order was placed with Lummus for a solvent extraction plant, using furfural, for lube oils—the Soviets themselves designed and constructed a furfural plant, which is described elsewhere in this issue.

Soviet cracking technique has been developed along the three methods: (1) low temperature cracking under high pressure, or liquid phase, which transforms large quantities of crude stock to light motor fuel; (2) high pressure cracking, or reforming, to improve quality of light motor fuel; and (3) cracking at high temperature and low pressure, or vapor phase, to yield high octane gasoline and large quantities of unsaturated hydro-carbon gases. The hopes built-up on vapor phase cracking were unjustified. Cost of operation became exorbitant without assuring stability of the end product and Russian engineers soon realized that tetræthyl lead could improve antiknock value of gasoline at less expense than cost of vapor phase cracking and reforming. Reducing has become an important process in Soviet refining; it was designed to lower the



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Cracking installation at the Saratov refinery, on the Volga river—one of the more modern enterprises of the Soviet government.

Russian Production And Run To Stills 1934-1937

(Barrels)

	1937	1936	1935	1934
Crude oil output:				
Planned	487,350,000	368,700,000	297,450,000	242,600,000
Actual	190,000,000*	191,694,000	176,688,000	168,600,000
Run to stills:				
Planned	426,800,000	354,600,000	251,500,000	205,000,000
Actual	180,000,000*	173,400,000	146,700,000	143,000,000

*Preliminary estimate.

viscosity of boiler fuel and is being employed today as a preliminary operation for deep cracking.

It was intended under the Piatiletka to raise the proportion of cracked gasoline to straight run gasoline produced in Russia from less than 20 percent in 1933 to at least 62 percent in 1937. It was anticipated that, of the cracking installations to be erected by the latter year, at least 90 units would be of liquid phase type and not less than 130 units of the vapor phase. This was rather premature, as their aspirations did not materialize.

Refinery Requirements For Second Piatiletka In 1937

	Tons	Percent of Total
Gasoline	6,000,000	15.9
Ligroin	2,100,000	5.5
Kerosene	7,000,000	18.6
Lubricating oil	2,100,000	5.5
Diesel oil	5,500,000	14.5
Fuel oil	11,000,000	29.1
Asphalt	1,000,000	2.7
Other products	3,100,000	8.2
Total	37,800,000	100.0

FURFURAL SOLVENT REFINING IN U. S. S. R.

STEADY GROWTH of Soviet motor transport, aviation and motorized agricultural equipment during the past few years has necessitated the production of lubricating oils of better quality—in increased volumes. Although it has been possible to increase the quantities produced, there has been a marked delay in improving the grades of oil turned out. Soviet refiners have too long tended to avoid introduction of improved technique, in the belief that inherent superior quality of Russian crude for lubricant manufacture rendered it unnecessary and that the gain, if any, in quality would be offset by the disproportionate expense involved. Advent of automobile manufacture with steadily increased compression ratios, faster rotation and greater pressure on bearings have gradually forced a change in opinion.

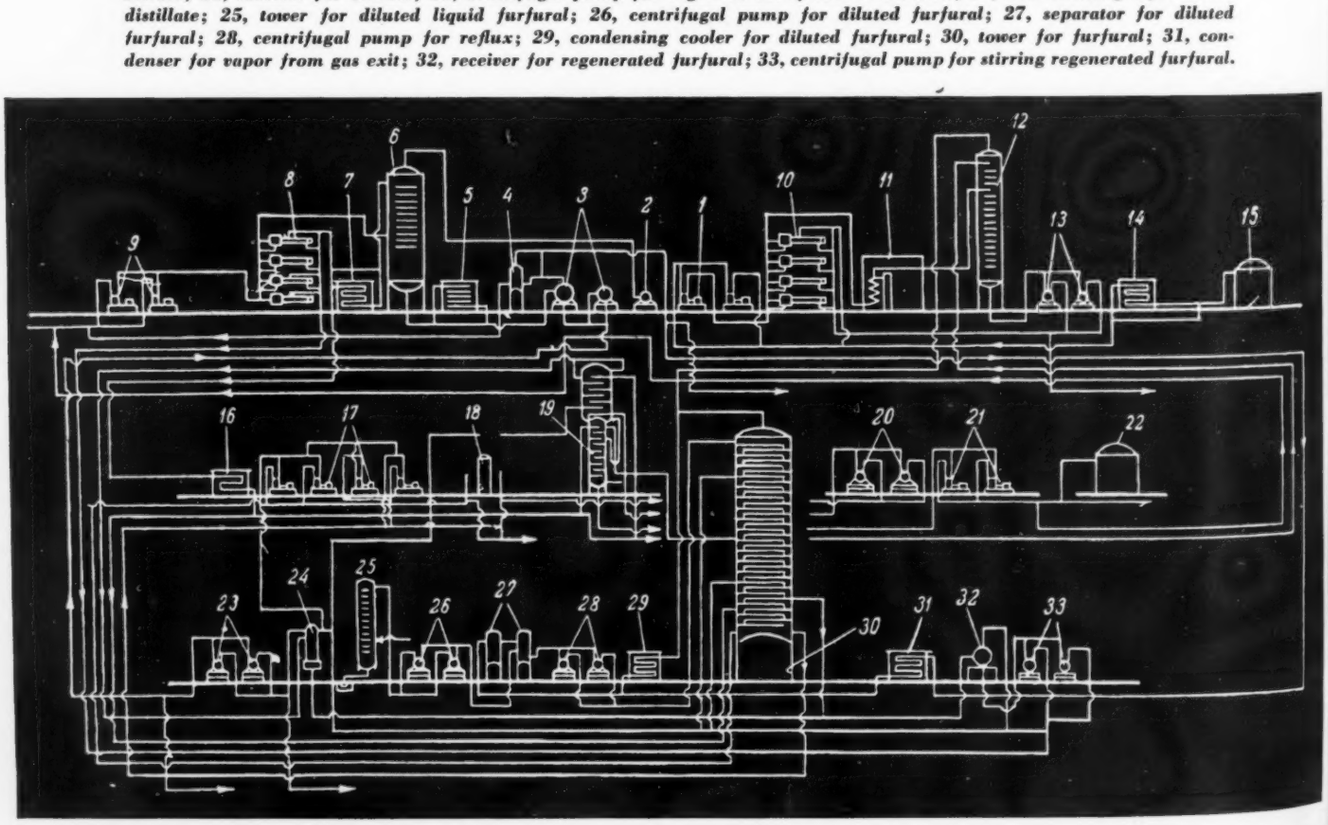
Prior to 1936 no color differentiation was made with lubricants for use in motor vehicles, and all grades had an appearance similar to that of fuel oil—but in that year changes were effected requiring motor oil color indices up to 3mm. (Dubosc). Viscosities were improved from 19 sec. Engler at 50 deg. C. to not less than 17½ secs. Engler at 50 deg., while more consideration is given to viscosity curve, etc,

Soviet technologists had become aware of the fact that domestic resources of naphthenic or paraffin base crudes were diminishing, and that increasing quantities of low grade crudes—containing aromatics, unsaturated hydrocarbons, asphaltum and sulphur—must be coped with. Ordinary methods of contact treatment with sulphuric acid cannot produce a high grade lubricating oil from these poorer crudes, aside from which the acid, while decomposing impurities to some extent, attacks valuable hydrocarbons and lowers the stability of the product.

The Soviet oil industry has had to face reality and to undertake domestic development of the various solvent refining processes, of which considerable laboratory experience had been gained by its technologists in the past six years. Academic nature of such experiments, inadequate contact between the research institutions, and lack of semi-industrial plants to test further the theoretical results have impeded decisions in regard to industrial projecting and large-scale planning of facilities.

When they completed an extensive study on selective treatment in 1935, leading to erection of an industrial installation at the Stalin group of refineries in Baku, E. Prosumentic and B. Ribak of Baku gave consideration to the following requirements of a solvent: selectivity and solubility, stability against oxidation, boiling point, latent heat of evaporation, vapor

Flow chart of installation for selective treatment of lubricating oil, designed by M. D. Sandler and M. Kantznelson of Baku: 1, Pumps for raffinate; 2, storage tank for raffinate solution; 3, settling tank for extraction; 4, recycling tank; 5, cooler for extraction solution; 6, tower for extraction; 7, submerged cooler for furfural; 8, heat exchanger for input; 9, steam pumps for input; 10, heat exchanger for raffinate; 12, tower for raffinate; 13, centrifugal pump for residue; 14, cooler for raffinate; 15, receiver for raffinate; 16, cooler for furfural reflux; 17, pump for raw extract solution; 18, furnace for extract; 19, tower for extract; 20, centrifugal pump for regeneration of extract solution; 21, steam pump for extract; 22, receiver for extract; 23, centrifugal pump for regeneration of extract solution; 24, heat exchanger for steam distillate; 25, tower for diluted liquid furfural; 26, centrifugal pump for diluted furfural; 27, separator for diluted furfural; 28, centrifugal pump for reflux; 29, condensing cooler for diluted furfural; 30, tower for furfural; 31, condenser for vapor from gas exit; 32, receiver for regenerated furfural; 33, centrifugal pump for stirring regenerated furfural.



pressure, corroding properties, toxicity, solubility in raffinate, solubility in water, and percent yield of raffinate. Stress was laid on meeting the demand for such a solvent as may be supplied from domestic raw materials, and therefore furfural was decided upon.

Type of Furfural Used in Soviet Refining

Boiling point at 760 mm. mercury	162 deg. C.
Freezing point	-37 deg. C.
Specific gravity at 15 deg. C.	1.164
Latent heat of evaporation	109.5 Cal.
Flash point, closed cup	39 deg. C.
Critical temperature	397 deg. C.
Critical pressure	54 atmos.
Solubility in water at 38 deg. C.	8.96 percent

Basic shortcomings of this solvent are its solubility in water, making it difficult to separate from the vapor condensate, and its tendency to become acid, requiring thorough hermetization from the influence of air. The advantage of higher yields of raffinate as compared with other solvents and abundance of domestic raw materials for its manufacture led to the decision to choose furfural.

The original design called for horizontal extract mixers and vacuum towers. Having

(Continued on page 171)

JAPANESE EXPANSION

of Refining Facilities

By Morio Otaki

JAPAN consumes about 28,000,000 bbl. of petroleum products annually. Of her total consumption, the Empire supplies nearly 2,800,000 bbl. or only 10 percent, while overseas supplies must be depended upon for about 90 percent of the national demand. Over 30 percent of Japanese receipts are imported in the form of crude while about 69 percent is delivered as finished products. Refineries handling imported crude are designed on a larger scale than those engaged in refining domestic crude. Most exceed 2,300 bbl. daily capacity. The capacity of refineries handling domestic crude is more restricted, and few reach the 1,900 bbl. mark.

Most refineries handling imported crude were erected in recent years, and are equipped with modern facilities such as pipe still distillation plants and cracking plants. Older refineries are continuously being modernized because the oil industry is a cardinal factor in the national fuel policy. Some of the pipe still distillation plants in general use by the domestic refining companies include Foster Wheeler, Badger and N. N. C. for treatment of crude oil; Kellog and N. N. C. for distillation of heavy oil; and Dubbs, Cross, N. N. C., Kokura, Schwalz and the Gyro for cracking, and Smith-Resley for reforming gasoline. The capacity of those pipe stills has expanded remarkably in recent years. Domestic pipe stills like the N. N. C. and Kokura, devised and erected by Japanese engineers, have been showing excellent results. Under the circumstances, it is likely that distillation plants to be erected in Japan will, in future, become completely Japanese. A similar tendency has been featuring orders for distillation equipment for coal tar and oil shale.

As the result of the operation of the Petroleum Industry Control Law, the government control over the different branches of the petroleum industry, activities such as refining, importing of crude oil, and marketing of finished products, has been greatly strengthened. Apparently due to this new development, domestic petroleum companies have begun to place an equal emphasis upon improvement in quality of finished products as upon increase in the volume of production. Under impetus of the government liquid fuel policy, many domestic companies have commenced activities for the expansion or improvement of their refining facilities. Three new large-scaled refineries have come on stream since the latter part of 1936. One of the trio was the refinery of Hayama Oil Company, erected at Funakawa, Akita Prefecture. This refinery, which handles crude available from the Omonogawa oilfield, was completed in October and commenced operation in November, 1936, The second was the Kwansai refinery of Japan Oil Company. It was completed and on stream in June, 1937, and has a daily refining capacity of 2,300 bbl. Largest of the three was the refinery of Chosen Oil Company, placed in operation in August, 1936 Erected on a site covering some 1,080,000 sq. ft. at Genzan, Korea, this refinery has a daily refining capacity exceeding 4,200 bbl. Chosen Oil Company was established in June, 1935, with the object of making the Chosen peninsula completely self-supplied in petroleum products.

Apparently in support of the national fuel self-sufficiency drive, the Ministry of Commerce and Industry issues licenses promptly to oil companies authorizing them to expand existing refining facilities. Since the start of the second half of 1936, the Ministry has issued about six permits for the erection of additional refining facilities.

Mitsubishi Oil Company has started work on the expansion of its distillation plant involving a 628,600 bbl. increase in its annual gasoline production, while Hayama Oil Company has commenced construction of an addition to its topping plant in order to expand its annual gasoline production by 125,700 bbl. Aikoku Oil Company has obtained government permission to expand its topping plant by adding 81,800 bbl. to its annual gasoline output. Maruzen Oil Company is well under way with the expansion of its topping and cracking plants. This project calls for an increase of 314,300 bbl. to the annual gasoline production of the company.

These schemes of refinery expansion are scheduled to be completed during 1937, or early in 1938.

Erection of the Badger-type vacuum pipe still at Osaka Mineral Oil Refinery, reconstruction of facilities at the Hokkaido and Akita refineries of Japan Oil Company, and the modernization of distillation equipment of the Kato refinery at Nagaoka, Niigata perfecture—all completed by the end of 1936—also served to expand the domestic oil refining capacity to a great extent.

At the end of June, 1937, there were 66 Japanese petroleum refineries operated by 53 owners. (It is believed that not all of these are autonomic, but that about half are in reality plants for treating semrefined products.—Ed.)

The continuous gasoline plant at Tsurumi refinery, Japan Oil Company.

National Refining Program in ITALY

Vesuvius presents an impressive background for Vacuum's refinery at Naples.

THE YEARS 1936 and 1937 will be remembered as the period of the most intense constructive activity of Italy in the petroleum field.

This activity has been an attempt to realize the program contemplated in the Royal Decree Law of November 2, 1933, which was converted into law No. 367 on February 8, 1934 and has been carried forward in spite of the difficulties of obtaining machinery and material.

In January 1937 there was completed the Aquila refinery in Trieste while the great cracking plants at Venice (DICSA) and at Naples (BENIT) were enlarged and will be ready for operation in a few months. The AGIP will operate the first and the Socony-Vacuum the second.

The year 1937 is also the period in which will have been accomplished the great project of the ANIC (a company created by the government with participation of the concerns AGIP, AIPA and Montecatini)

namely, the establishment of the hydrogenation plants at Bari and Livorno.

These hydrogenation plants will operate on various cycles, either in normal atmospheric distillation, cracking, stabilization and refining, or (and this will be the principal line), by hydrogenation in liquid and vapor phases. The plants have been designed for treatment both of native mineral oils, or oils obtained from outside sources under national control, particularly Albanian oil, and eventually will treat products obtained from the exploitation of asphaltic rocks, bituminous schists, and lignites.

The plants designed for the ANIC will also include facilities for solvent refining, vacuum distillation, and processes for obtaining lubricating oils and paraffin.

WORLD PETROLEUM has already described the ANIC plant in its August, 1937, number. Some information on the two refineries recently completed in Venice and in Naples, also the installation which is in course of erection at Tripoli (in the Italian colony of Libya) is contained in this article. Data relating to the other refineries will be found in Table 2 and the locations are shown on the map on page 153.

AGIP AT VENICE

The mineral oil refinery which the AGIP finished building this year at Porto Marghera is furnished with all the most modern machinery. This new plant represents a complement of the other existing plants. When finally expanded it will be able to work annually 3,500,000 to 4,200,000 bbl. of crude oil.

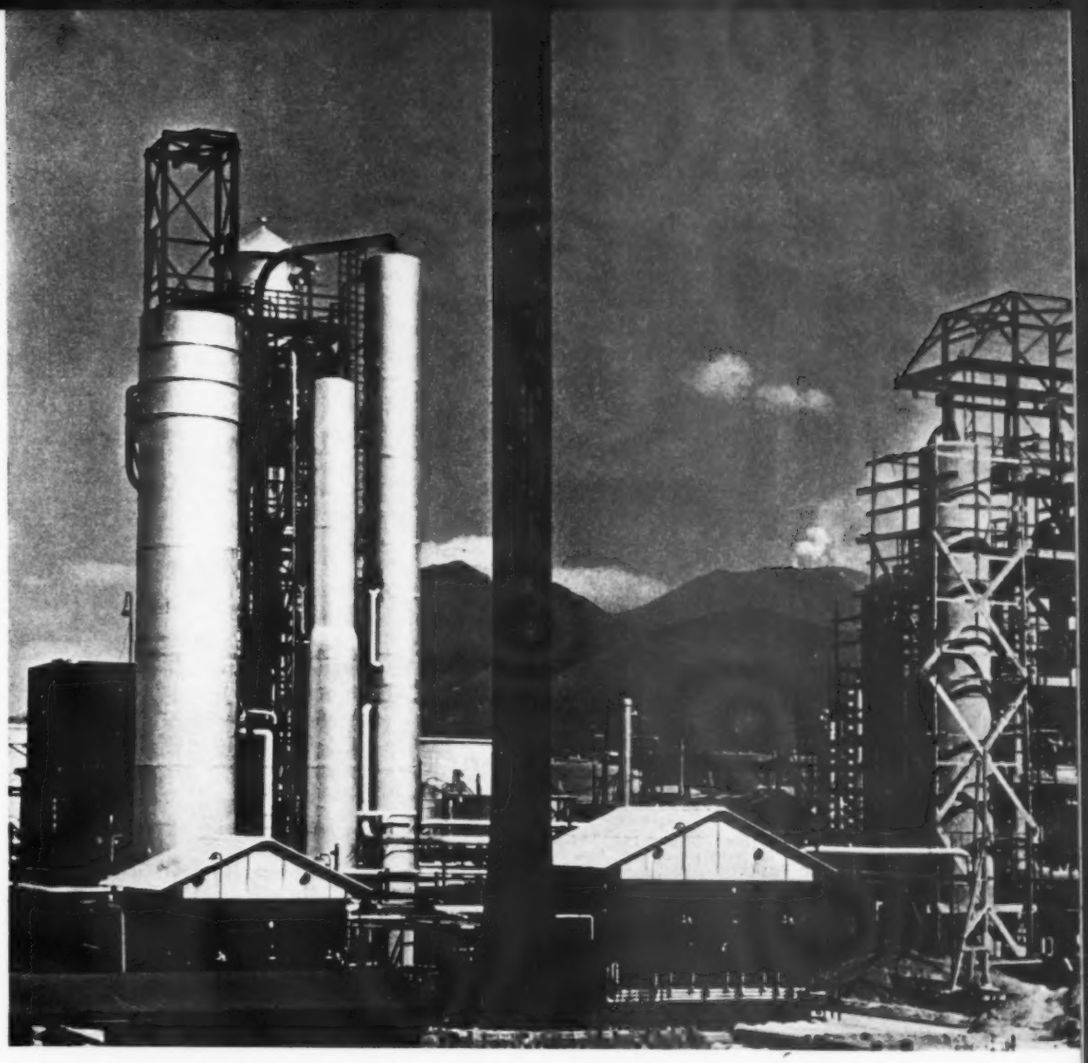
Besides gasoline this plant will also produce illuminating oil and agricultural petrol, gas oil, diesel oil, fuel oil, tar, and petroleum coke. In a short time it will also be able to produce lubricating oil and paraffin by means of modern equipment. Besides, steps have been taken for the rational utilization of the gases produced in the refinery. Among such products will be liquid butane and propane, and other products of interest to the national industry.

The construction and the management of this plant have been confided to a company formed for the purpose, and with which the AGIP has made a contract regarding the furnishing of gas. The storage capacity for raw materials is about 160,000 cu. meters. Storage for finished products amounts to about 32,000 cu. meters and storage for products in process of manufacture is 8,000 cu. meters. Ample facilities have been provided for the arrival and departure of raw materials and finished products by a connection with the Vittorio Emanuele Canal, where two large tankships can load or unload at the same time.

The refinery, which the Socony-Vacuum Oil Company has built at Naples, through its Italian subsidiary the Soc. An. It. Vacuum Oil Company, represents an enlargement of a pre-existing refinery built by BENIT and which has been operated for five or six years with two Dubbs cracking units. It will have a working capacity of 1,400,000 bbl. of crude oil per year, from which the following products will be obtained:

595,000 bbl. of gasoline (including 85,000 bbl. of aviation gasoline).
100,750 bbl. of refined kerosene.
130,500 bbl. of special lubricants.
362,500 bbl. of gas oil.
No limit has been placed on the production of fuel oil.

This large plant will cover an area of at least 2,500,000 sq. meters. It will receive crude oil through a three kilometer pipeline which has already been built and which extends along a road reaching to the port, and ends on a large, wide dock which will give ample accommodation to 15,000 to 20,000-ton tankships. This refinery began full operation in September 1937.



Extension and modernization of Italian refineries has probably reached the peak of activity—Naples refinery of Socony-Vaccum.

A.C.I.O.M. AT TRIPOLI

This refinery is being built on ground to the east of the city in a locality ideally suited for an oil plant. The plant and its accessories will cover an area of about 400,000 square meters along the old wall of the city, at an elevation of about 12 meters above sea level.

The principal approach to the refinery is along the great Libyan shore road, which is the highway backbone of the colony and will permit rapid distribution of the products by tank cars and trailers.

A series of four pipelines about 2,500 meters long will connect the refinery with the dock where the tankships discharge the crude oil, and where finished products can be dispensed to lighters in the port.

The annual working capacity will at first be about 730,000 bbl. of crude, with a possibility of a quick increase to 1,095,000 bbl.

The complete installation will comprise distillation, cracking, re-distillation and refining units. There will be 48 storage tanks with a capacity of about 54,000 cubic meters for crude and finished products. The central electric plant will have a capacity of 4,000 kw. per 24 hours with a reserve plant and two transformers. Three boilers will have a capacity for producing 11,000 tons of steam per hour. The amount of

metal which will go into the construction is about 3,000 tons. Roads and passages within the plant will have a combined length of 1,500 meters. The combined supply of fresh and sea water will amount to about 15,000 liters per minute. The necessary pumps and electric motors will number about 50. Among the important accessory installations is the one provided for separation and purification of combustible gases for local use, with particular reference to obtaining butane and propane which will be compressed in drums for domestic and industrial uses even in remote places. Other important features are a chemical laboratory, a machine shop, a central pumping station, a central heating station, loading platform and a station for the road trucks and trailers by which a large proportion of the products of the refinery will be transported to different parts of the colony.

A report on the progress of the construction dated Tripoli, September 10, 1937 reads as follows:

Initial Production of Tripoli Refinery

	Barrels
Aviation gasoline	255
Light gasoline	340
Heavy gasoline	340
Solvent gasoline	250
Kerosene	275
Gas oil	255
Fuel oil	290
Asphalt (tons)	25

"The work of constructing the Tripoli refinery, which is one of the first objectives of the imperial economy, has now been well begun.

"Plans having been finished we are now proceeding to acquire the land whereupon we shall proceed with the building work. The plant has been designed not only to supply the needs of the colony but also to engage in exportation."

TABLE I

Petroleum Refineries in Existence in Italy in 1931

Ownership of Control	Refinery	Location	Capital (Lire)	Equipment	Working Capacity in tons per year	Products
A.G.I.P.	Raffineria Olii Minerali S.A. (ROMSA)	Fiume	25,000,000	Distillation and refining Has Holmes-Manley cracking plant	60,000	Gasoline, kerosene, gas oil lubricating oil, paraffin and coke
STANDARD OIL	Raffineria Triestea S.A.	Trieste	10,000,000	Distillation and refining	50,000	Chiefly lubricating oil.
STANDARD OIL	Società Petrolifera Italiana	Fornovo Taro (Parma)	25,000,000	Distillation of national crude (side line)	3,000	Gasoline.
ROYAL DUTCH SHELL	Soc. per l'Industria Italiana del Petrolio	Spezia	25,000,000	Cracking plant for oil residues (2 Dubbs units)	70,000	Gasoline, Diesel oil, coke.
INDEPENDENT	Soc. Distillazione Italiana Comb. (DISCA)	Venice	15,000,000	Cracking plant for oil residues (1 Dubbs unit)	30,000	Gasoline, gas oil, etc.
PETROLINA DI BRUXELLES	Soc. An. Benzina Italiana (BENIT)	Naples	15,000,000	Cracking plant (2 Dubbs units)	70,000	Gasoline, gas oil, etc.
INDEPENDENT	Soc. An. Petroli d'Italia	Fiorenzuola d'Arda (Piacenza)	14,000,000	Distillation of national crude (side line)	3,000	Gasoline.

TABLE II

Situation of Italian Petroleum Refineries in March 1937

Group	Name, Office and Capital	Location of Plant	Character of Operation and Plant	Approx. Capacity in tons crude a year (1)	History
A.G.I.P.	Azienda Generale Italiana Petroli (AGIP) Rome L. 300,000,000	Porto Marghera (Venice)	Distillation, Refining, 2 Dubbs cracking units	450-600,000	Has been cracking for several years; the other plants will operate in 1937.
	Raffineria Olii Minerali S.A. (ROMSA) Fiume L. 25,000,000	Fiume	Distillation, Refining and Holmes-Manley cracking unit	120,000	At work from 1882 with cracking since 1929. Enlargements in process of installation
A.G.I.P. A.I.P.A. MONTECATINI	Azienda Nazionale Idrogenazione Combustibili (ANIC), Milan L. 500,000,000	Bari and Livorno	Complete operating plant including hydrogenation	370,000	In course of construction
SOCONY Vacuum (New York)	Soc. Raffineria di Napoli Rome L. 34,000,000	Naples	Distillation, Refining, Duo-Sol Process, 2 Dubbs cracking units	200,000	Has been cracking for 5-6 years other equipment to be installed in 1937
	Soc. Italo-Americana pel Petrolio Genova L. 250,000,000	Trieste	Distillation and refining	160,000	Operating since 1892
STANDARD (New Jersey)	Soc. Petrolifera Italiana Fornovo Taro (Parma) L. 25,000,000	Foronovo Taro (Parma)	Distillation of national crude	20,000	Operating for many years
ROYAL DUTCH SHELL	Soc. per l'Industria Italiana del petrolio (INPET) Genova L. 45,000,000	Spezia	2 Dubbs cracking units	100-120,000 petroleum residue	Shut down pending decision to enlarge for complete cycle
—	Societa "Aquila" Trieste L. 25,000,000	Zaule (Trieste)	Distillation, Refining, Foster Wheeler-Borsig refining with Edeleanu solvent	300-400,000	Operating since January 1937
AZIENDA COMMERCIALE ITALIANA OLII MINERALI S.A.	Raffineria di Olii Minerali per l'Africa del Nord—(R.O.M.A.-N.A.) L. 10,000,000	Tripoli	Distillation, refining and cracking	100-150,000	Projected; to be built by March 1939.
PETROLI D'ITALIA	Petroli d'Italia Milan L. 14,000,000	Fiorenzuola d'Arda (Piacenza)	Distillation of national crude	5-10,000	Has been operating for a decade
A.B.C.D.	Raffineria ABCD Rome L. 10,000,000	Rome	Operates on oil from rock asphalt	—	Enlargements are projected

1) The working capacity of the plants is usually understood as the quantity of crude petroleum which it is possible to work during the year. The figures are approximate and in most cases indicate the maximum capacity, especially as regards the smaller plants. As regards yields of finished products it is to be noted that with the same quantity of crude put in operation the yields will be quite different according to whether the plant is operating wich simple distillation equipment or whether the plant is equipped for cracking or hydrogenation; the gasoline yields will therefore be 20, 40 or 80 percent from the same crude.

NOTE.—Sufficient data is not yet in hand for including in the above table the Societa "Permolio" of Milan (allied with the A.B.C.D.), the S.A. "Lombarda Petroli" also of Milan, and the Soc. "Carbol", which have small production licenses for 1937 amounting respectively to 19,000 tons (of which 12,000 are for bitumen) 6,000 and 7,500 tons annually.

CONCLUSIONS

An examination of the accompanying tables will allow some interesting observations:

The extraordinary development of the Italian petroleum industry will be seen by comparing table I (dated 1931) with table II (of 1937.)

The production figures for various petroleum products obtained by Italian refineries from 1932 to 1937 (table III) shows the large increase of activity which occured in 1936 and 1937 whereas in the years 1934-1935 and part of 1936 there was a slowing down due to tariff complications.

The raw materials used by the Italian plants have undergone a change; previously much fuel oil was imported for cracking. Now mostly crude petroleum is imported and for this reason the plants have been transformed so as to work a complete cycle (in 1936 about 2,100,000 bbl. of crude were imported).

The principal groups operating in Italy are government companies (AGIP-ANIC). Table IV which gives the distribution of operating licenses for 1937, does not yet include the ANIC.

When the ANIC begins operating in 1938 it will evidently have a large production of gasoline and certain other products in excess of domestic requirements, and will have to resort to exportation; a similar situation already confronts the Aquila. It is also evident that this situation will continue to restrict the importation of finished products

TABLE III

Production of Italian Refineries

Year	Gasoline	Refined Kerosene	Gas Oil	Lubricating Oils for Different Uses	Fuel Oil	Paraffin	Petroleum Bitumen	Petroleum Coke
				(in tons)				
1932	156,873	42,641	23,387	21,938	127,458	655	11,557	31,657
1933	163,021	42,185	22,681	25,099	138,780	775	13,836	34,424
1934	125,795	37,848	36,804	21,011	75,965	546	12,059	37,406
1935	130,071	49,870	33,194	24,314	93,933	546	26,217	19,696
1936	130,398	41,143	38,417	20,795	109,903	593	45,571	26,620
1936 (7 mos.)	67,025	23,847	17,689	13,012	48,598	363	26,553	14,011
1937 (7 mos.)	139,471	55,305	56,834	28,696	158,026	208	41,103	17,271

into Italy, and these imports will be replaced by the importation of crude oil and residues.

Standard Oil Co. of New Jersey, which in Italy had only a small refinery at Trieste, is adjusting itself to this transformation in the Italian market by re-organizing its own extensive sales system in Italy by an agreement with Socony-Vacuum, which will assign to the Standard Oil the products of the Naples refinery.

Petrolea, a company created by Russia and later bought by the Fiat automobile concern, has no operating plant in Italy. Russian oil products are destined to disappear from the Italian market. Roumania also is excluded from the operating Italian oil industry. The Creditul Minier, through its subsidiary A.P.I.R. which now sells in Italy only finished products, has asked permission to establish a refinery at Livorno, but this application is not likely to be granted because there is already a sufficiency of authorized plants.

Comparing the actual figures for Italian consumption of petroleum products (about 22,500,000 bbl.) with the figures for the probable operating capacity of the refineries in 1939-1940 (15,000,000 bbl.) it will be seen that whereas the oil industry is not yet capable of meeting the total requirements of the country, it is nevertheless quite able to supply more than the requirements for motor fuel, due to the development which has been started in the use of substitute fuel, especially alcohol.

As regards the requirements for lubricating oils these have been entirely covered. There remains the field of fuel oil, of which the country has a deficiency due to the scarcity of solid fuels.

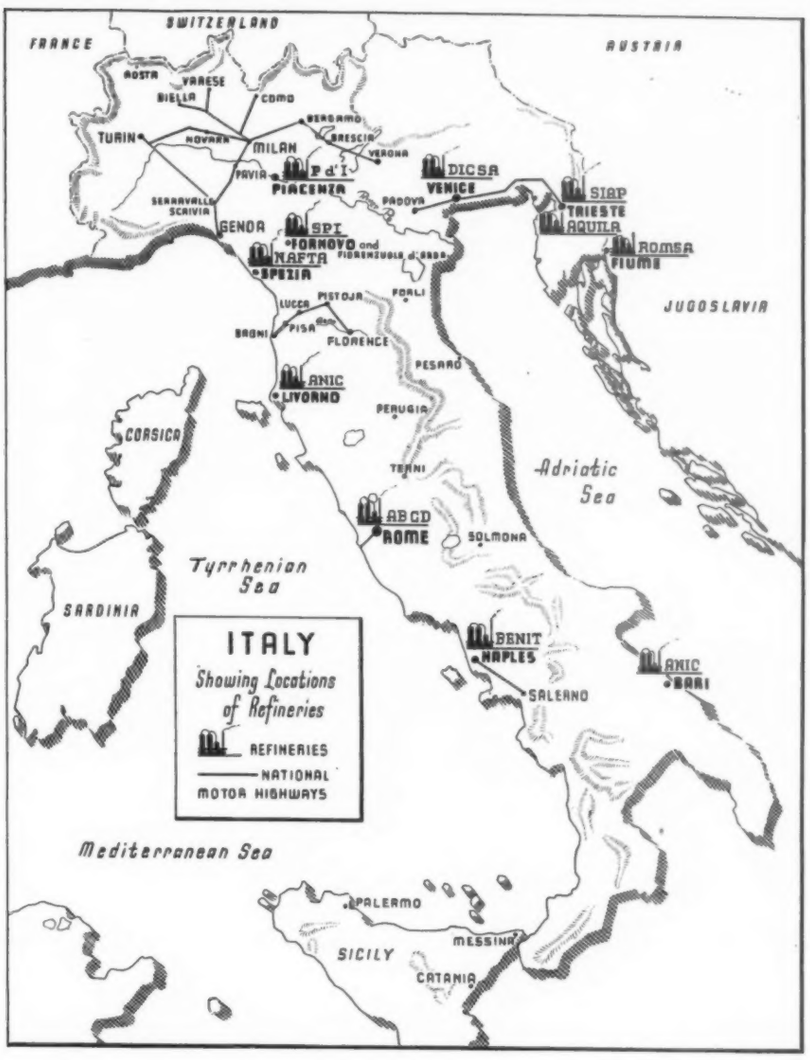
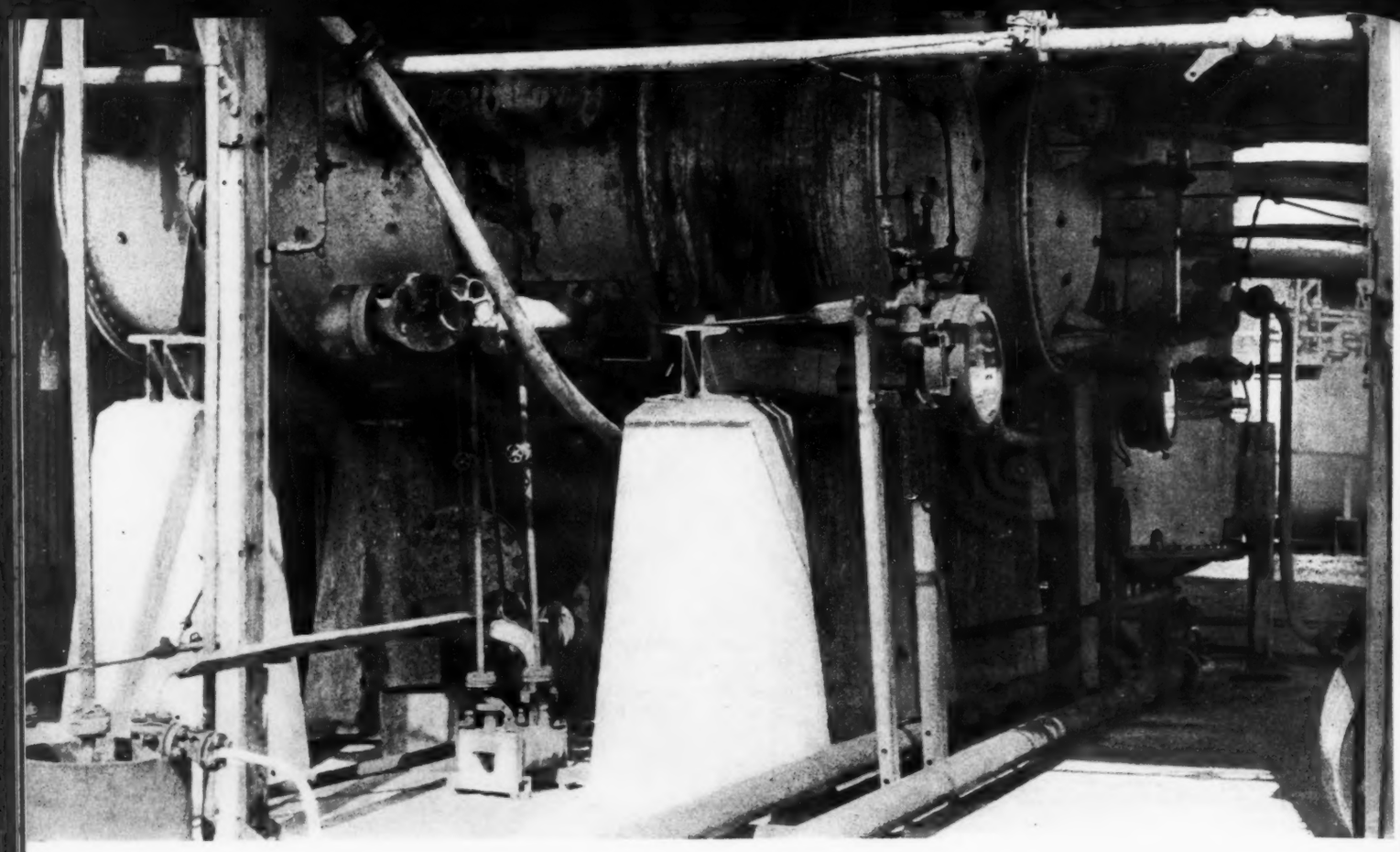


TABLE IV

Italian Refinery Production and Import Licenses for 1937

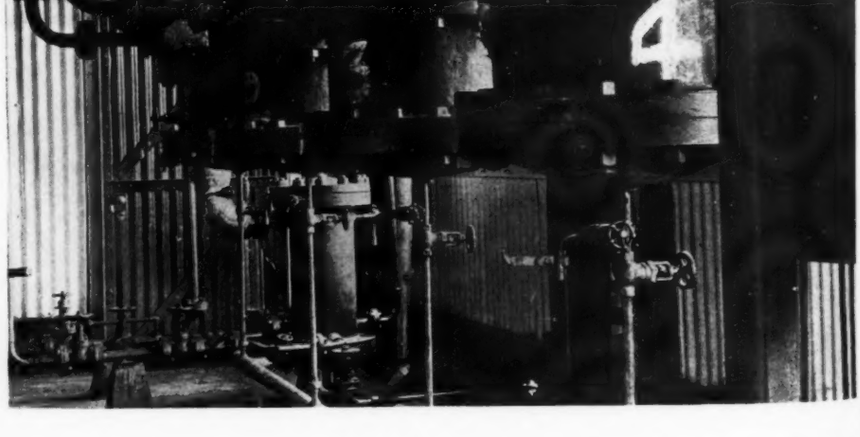
		AUTO AND AIR-PLANE GASOLINE		KEROSENE		WHITE SPIRIT		GAS OIL AND DIESEL OIL		FUEL OIL for Boilers and Furnaces		LUBRICANTS		BITUMEN		TOTAL
		Importation	Production	Importation of agricultural oil	Production of illuminating oil	Importation	Production	Importation	Production	Importation	Production	Importation	Production	Importation	Production	
AGIP	Azienda Gener. Italiana Petroli and S.A. Romsa	5,800	100,000	32,000	25,000	....	5,000	32,000	40,000	170,000	unlimited	11,560	6,000	....	28,000	
	TOTAL "AGIP"	105,800		57,000		5,000		72,000		170,000		17,560		28,000		455,360
STANDARD	Siap and Raffineria Triestina	113,200 (1)	4,000	29,000 (1)	14,000	....	....	75,500 (1)	8,500	145,000	unlimited	....	18,000	....	15,000	
	Petrolifera	....	11,000	....	3,000	....	....	....	....	....	....	....	....	....	....	
	Bedford	....	....	....	....	....	....	....	....	....	....	4,760	....	....	....	
	TOTAL STANDARD	128,200		46,000		....		84,000		145,000		22,760		15,000		440,960
ROYAL DUTCH SHELL	Inpet	27,400	65,000	15,000	14,000	7,000	....	82,000	8,000	130,000	unlimited	5,440	....	....	....	
	U.I.L.	....	....	....	....	....	....	....	....	....	....	13,600	....	....	....	
	TOTAL R.D.-S.	92,400		29,000		7,000		90,000		130,000		19,040		....		367,440
VACUUM	Raffineria di Napoli and Benit	....	(69,000)	....	(13,000)	....	....	....	(30,500)	....	unlimited	3,060	7,500	....	....	
	Sipom	....	....	....	....	....	....	....	....	....	....	500	....	....	....	
	TOTAL VACUUM	....		....		....		....		....		11,060		....		11,060
SOC. AN. AQUILA—TRIESTE		....	28,000	....	10,000	....	2,000	....	20,000	....	unlimited	....	10,000	....	12,000	82,000
A.B.C.D.—Rome		....	5,000	....	1,000	....	3,000	....	2,000	....	unlimited	....	5,000	....	5,000	21,000
S.A. Permolio—Milan		....	2,000	....	....	....	....	....	4,000	....	unlimited	....	1,000	....	12,000	19,000
Soc. Carboi		....	2,000	....	2,000	....	....	....	2,500	....	unlimited	....	1,000	....	....	7,500
S.A. Lombarda Petroli		....	2,000	....	1,000	....	1,000	....	2,000	....	unlimited	....	....	....	....	6,000
S.A. Petroli d'Italia		....	1,000	....	2,000	....	....	....	1,200	....	unlimited	....	....	....	....	4,200
TOTAL SMALL REFINERIES		12,000		6,000		00		11,700		....		7,000		17,000		57,700

(1) Including also production of Vacuum.



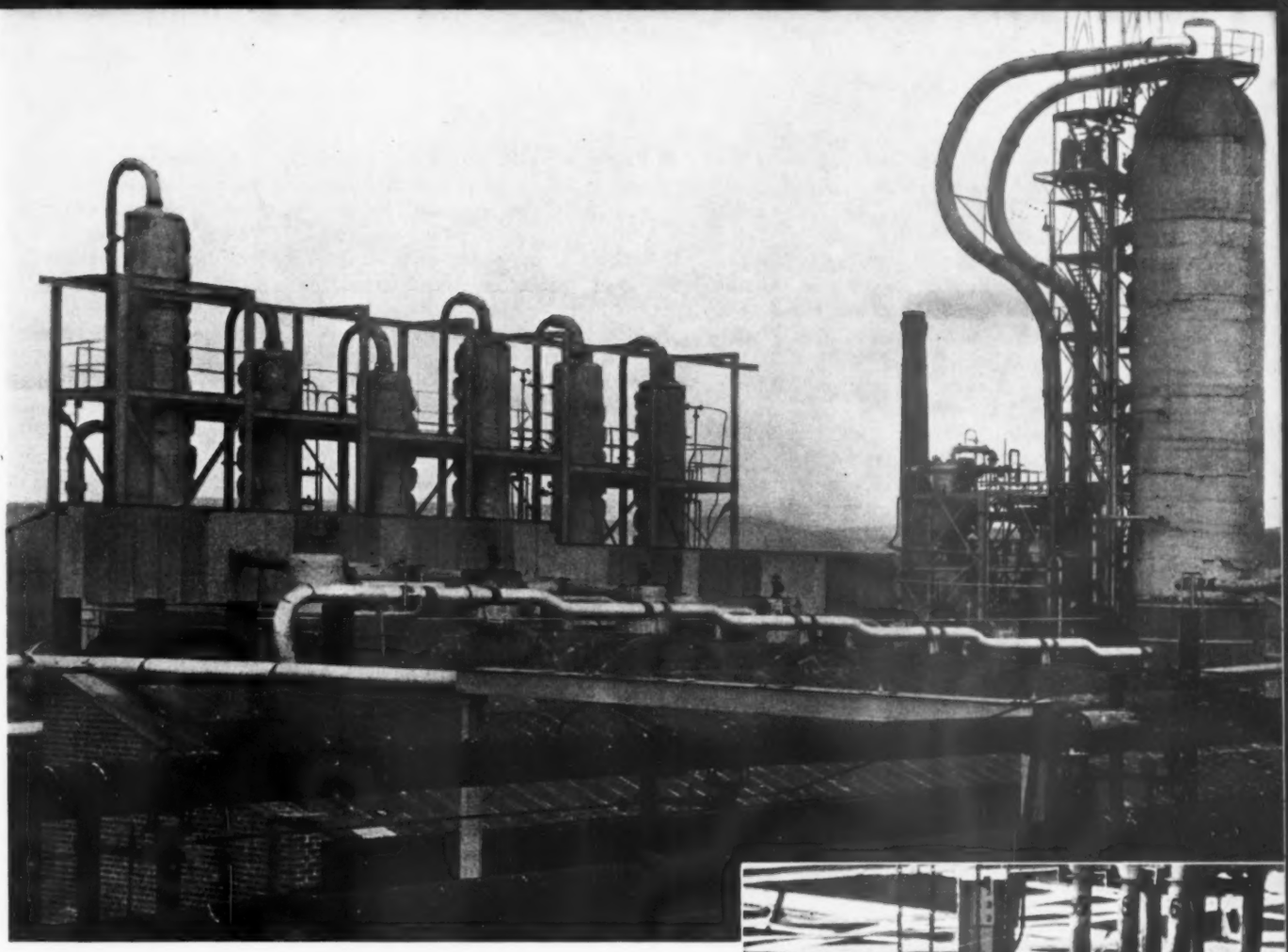
LLANDARCY— Current Construction to Eliminate Boiler Stills, Improve Lube Treatment

Starting as a Simple Topping Plant Designed to Be a Smaller Edition of Abadan During the War, Llandarcy Is Becoming One of England's Most Complete and Up-to-Date Refineries.



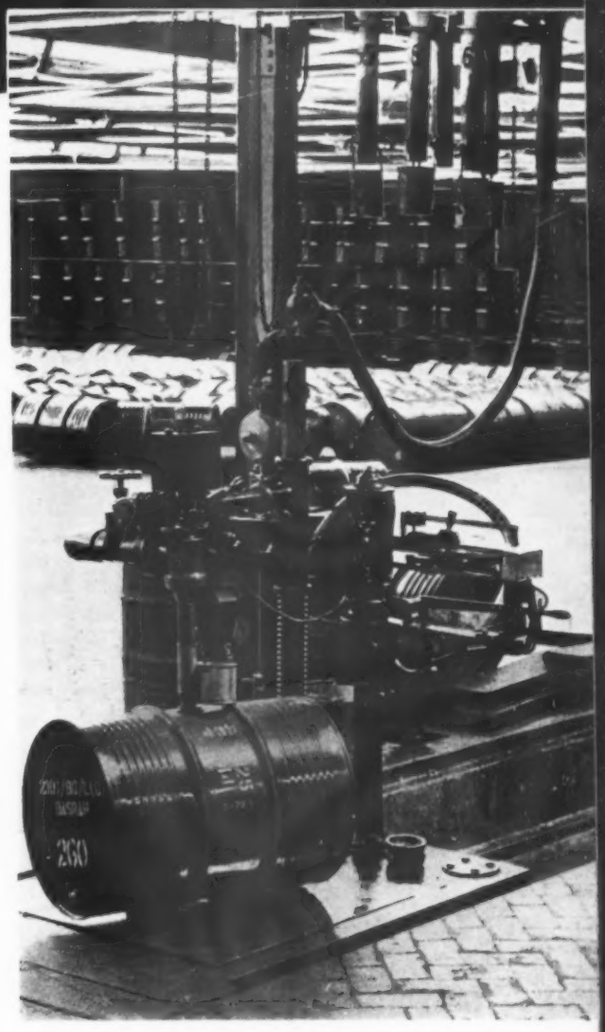
THE REFINERY was laid out during the war as a small edition of the original Abadan plant with the purpose of producing from crude oil imported from Abadan, motor spirit, kerosene, gas oil and fuel residue, together with some amount of lubricating oil and wax. Its original daily capacity was of the order of 7,000 bbl. of crude oil, run on a double bench of shell stills, the distillate from which was re-run on two oil-fired shell still benches. This capacity was subsequently augmented by allocating these two redistillation benches to crude, by building a further bench for crude distillation, and by providing a group of steam heated stills for re-distillation of the light distillate. This brought the total capacity up to about 24,000 bbl. per day, which amount entailed some considerable volume of reshipment as the local demands within economic rail car and road verhicle delivery were not sufficient to absorb all the products treated at the plant.

The first stage of this early process consisted of distilling off in stills of Lancashire boiler type some 35 percent of the crude in the form of O. R. D. (Once Run Distillate). This subsequently had to be redistilled to separate out the benzene from the heavier kerosene. The residue from the crude distillation was passed to a residue bench where the heavy kerosenes and gas oils were distilled off, while



Upper left, reaction vessels in Anglo - Iranian's Llandarcy di-isobutylene plant; lower left, view of the bottoms of reaction vessels in the hydrogenation plant.

Upper right, the modern lubricating oil unit shown on the right side of the picture supersedes the shell still plant on the left; lower right, automatic filling and weighing machine used at Llandarcy.



the residue from this bench was redistilled on the old pitch bench to give waxy lubricating oil cuts with a heavy residue which was blended back into fuel.

The spirit after redistillation was batch washed with hypochlorite solution and soda to give a spirit which was then satisfactory for market requirements; while the kerosene was merely filtered through powdered and roasted bauxite. The gas oil was sold untreated; the small amount of lubricating oil, after de-waxing by refrigeration and filter pressing, was acid washed and clay treated in batch washers; while the wax was sweated and bauxite filtered before slabbing for sale. There was also a large percentage of fuel sold as furnace oil and bunkers.

This was the simple scheme of operation on which the refinery was planned during the war, and commissioned in 1921 as an example of up-to-date plant. Since that time continuously increasing demands have been made on the refineries of the world for improved products, as a result of the large expenditure of money and effort made by the industry on research and development. Every petroleum product, from aviation spirit to heavy lubricating oil and bitumen, has been affected in this way. Motor spirit has perforce been improved out of all knowledge, and it has sometimes been thought out of all reason, by the combined effect of competitive action by the producers and the increasing demands of engine designers.

The volatility has been increased to give easy starting, yet controlled to avoid vapor lock in the petrol supply; its end point has been lowered to avoid crankcase dilution and to improve carburetion; and its anti-knock qualities as measured by its octane number, have been continuously and radically improved, but with careful watch on the gum forming propensities which followed the early improvements in anti-knock quality.

Aviation spirit, kerosene, white spirit and light diesel fuel have all followed suit, while in the case of lubricating oil still more drastic action has been taken. To improve the quality of a lubricant in the way of better viscosity index, lower carbon residue and resistance to oxidation, and greater stability, expensive chemical solvent processes have been perfected which have the effect of removing the unsatisfactory constituents of the lubricant, albeit at the expense of considerable yield.

All these tendencies have resulted in very great changes in the processes and plant at Llandarcy; so great in fact that in 12 months or so when the current program of improvements is completed there will be very little indeed of the original plant remaining in operation.

Among the first major additions in the way of new plant were five large cracking plants, each in turn the last word at the time of its construction. These cracking plants were originally installed to increase the motor spirit yield by cracking fuel and gas oils. Subsequently it was found that cracked spirit had better anti-knock properties than straight run spirit. Cracking therefore became a desirable process from quality considerations also, until finally straight spirit itself was cracked or reformed to improve its octane number.

Gases from this cracking process introduced a new by-product, which was dealt with by new equipment in the form of compression and stabilization plants to enable gas of controlled quality to be sold for industrial use. Later this plant was improved to allow the preparation of liquid gases such as butane which is now becoming so well known, and propane for which new markets are being explored.

Still more recently a special plant for the preparation of di-isobutylene from cracked gasoline, and an experimental plant for its hydrogenation into iso-octane have been brought into commission. This has been demonstrated as a method of equipping refineries to cater for the most exacting demands of the aircraft industry for special fuels.

Quite early in the development of the refinery, a solvent treating plant using liquid SO_2 was installed and used to improve the quality of kerosene and white spirit by a reduction of the proportion of aromatic hydrocarbons in these products. Kerosenes thus refined have less tendency to smoke, and white spirit so prepared is more resistant to the repeated re-distillation which it encounters in use.

A Sharples centrifugal de-waxing plant was also provided to enable the amorphous wax content of the heavy lubricating oil to be removed by centrifuging after dilution with naphtha and cooling. The raw material for this plant was obtained from the old pitch bench to which vacuum distillation equipment was added to enable this heavy lubricating oil cut to be distilled off without undue amount of cracking.

A recent decision was taken to modernise completely and extend the plant at Llandarcy, and in particular to provide the most up-to-date plant for large scale lubricating oil manufacture.

The new program at Llandarcy has the following aims:—

1. To replace the old boiler stills with efficient continuous pipe-still plant.
2. To improve and extend the lubricating oil distillation and treatment plant so as to refine fully all the heavier constituents of the crude into the best quality and most valuable lubricating oils, waxes and bitumens, and so reduce to a minimum the production of bunker and furnace oils.

A total input to the refinery was settled at a figure which would in general allow the local market within economic rail car radius to be supplied with the lighter products such as motor spirit, kerosene, gas oil and light Diesel fuel, and on this input basis provision was made for producing from the residue the maximum quantity of high grade lubricating oils, waxes and bitumens. This figure of input was settled at about 8,170 bbl. per day.

The first step in the new program consisted of the replacement of the original shell still distillation benches by one modern continuous pipe-still. This will be capable of doing in one operation the work of all the old benches which comprised five crude benches, one lubricating oil bench and two pitch benches, while occupying less than the area of one of them.

This new unit, which is now in course of construction, consists essentially of three fractionating towers in series. The first works under pressure, the second at atmospheric pressure and the third under reduced pressure, the heat for the pressure tower being supplied by heat exchange from distillates and residues produced in the second and third towers, each of which has its own pipe-still heater.

From this unit will be obtained the required ranges of motor spirit, white spirit, kerosene and gas oil, which thereafter will be subjected to normal treatments in the way of acid or SO_2 treatment, and re-running in certain cases to form the finished products. The advantages of this distillation over that obtained with existing equipment will be the greater uniformity of products and the ability to obtain the maximum quantities of any given boiling range owing to the close fractionation obtained on the new column.

From the vacuum tower of this new unit will be obtained the heavy gas oil and the various grades of lubricating oil base obtainable from the crude, with a bitumen residue run off continuously from the bottom of the column.

By adjustment of the operating conditions such as quantity of feed, temperature and pressure of column, and quantity of reflux at various points in the column, it is possible to arrange for wide variations in the quantity and quality of products, and in this way to provide the flexibility needed to meet marketing requirements.

The second stage in the reconstruction program involves the provision of a modern solvent de-waxing and extraction plant. It was necessary to provide an extension of the existing centrifugal de-waxing capacity, and the opportunity was therefore taken to provide a later and more satisfactory type of de-waxing equipment which did not suffer from the disadvantages and rather high cost of operation of the existing process.

After considerable investigation into available processes, it was finally decided to adopt the Edeleanu Company's SO_2-Benzol process of solvent de-waxing which operates by the continuous removal through rotary filters of wax precipitated by the auto-chilling of the solvent due to evaporation induced by change of pressure. An added recommendation of this process was the possibility of combining with this de-waxing plant a solvent extraction plant utilising the same dual solvents, viz:— SO_2-Benzol in rather different proportions.

The object of this latter plant is to separate out from the lubricating oil base the high viscosity index constituents, or paraffinic bodies, from the less saturated hydrocarbons. The demands of modern internal combustion engines have made it essential that lubricating oils should be selectively extracted in order to retain only those constituents which have the lowest rate of change of viscosity with temperature, and which are also stable aginst de-composition and oxydation at the high temperatures met with in modern internal combustion engines.

The amount of high class oil of this type is very much less than of the medium quality previously marketed, but whereas acid refining for medium quality gave irrecoverable losses as sludge, these new processes enable every quality of oil in the crude to be isolated and suitably used; thus the small amount of very high class lubricating oil is accompanied by quantities of industrial and fuel oil grades, all of which can be recovered and used either alone or as blended constituents of bitumens or of industrial lubricating oils.

The combined solvent extraction and de-waxing plant will be situated in one large building, and will contain compressors, vacuum pumps, mixing and separating vessels, chilling coils, rotary filters and the various solvent evaporators necessary for the removal of the solvent after the separation has been completed. All this plant will be sited in such a way that the vital control centres will be adjacent to each other, so that the minimum number of operatives will be required; and all pressures, temperatures, flow rates, etc., will be indicated on a central control board furnished with recording meters.

This plant has the merit of being very efficient and extremely flexible, this latter feature being dependent upon the fact that the same solvent is used both for the de-waxing and for the solvent extraction process, which means that either process

can come first in the sequence of operations according to which is found best and most economical in practice. This plant has recently been ordered, and the detailed designs are now in course of preparation. It is expected that it will be ready for commissioning in about 12 months' time.

A small amount of finishing treatment is required to complete the refining of oils selected by solvent extraction processes, and this will be provided by a continuous acid treating plant and a modern plant for the high temperature contacting of oils with refining clay. The acid treating plant which is now being considered will embody a system of continuous and intimate agitation of the acid with the oil and subsequent separation continuously in centrifugal separators. In the final process of high temperature clay treatment, the oil will be automatically mixed with an activated clay and pumped continuously through a pipe-still where the mixture of clay and oil will be brought rapidly to the necessary temperature of about 350 deg. F. Thereafter, it will be rapidly cooled and passed through bottom-opening filter presses for removal of the clay.

The lubricating oils will be passed through these various plants either in plugs of several days' run of the required viscosity oil to give the desired finished viscosity, or alternatively, will be re-run, after de-waxing, in the existing vacuum pipe-still equipment into the various viscosities necessary to give the required finished grades after completion of treatment. Thereafter, the oils will be passed to finished storage and dispatched either in rail cars, or blended and packed in small packages in the new lubricating oil blending and despatch plant which has just been completed at Llandarcy.

This plant is laid out as a large, well-lighted, unimpeded area. There is a central aisle containing overhead a large number of blending tanks fitted with steam heating coils and air agitation arrangements, above which is a series of pipes bringing the main grades of lubricating oil from the refinery storage. Switching devices allow the desired quantities of the various basic grades to be diverted into any tank, where appropriate blends can be made as required. From these overhead tanks there are flexible pipes connected to automatic weighing machines which can be set to give a predetermined weight to any package placed on their tables for filling. These filling machines vary in size from that required to fill a one-gallon tin up to a large machine for filling 50-gal. drums.

On one side of this central aisle is the reception side for empty packages, and for receiving the returned 40-gal. drums for cleaning, re-conditioning and painting; and on the other side of this central filling aisle is a large completely free area for the storage of filled packages waiting for removal by rail or road vehicle for distribution or for shipment at the docks.

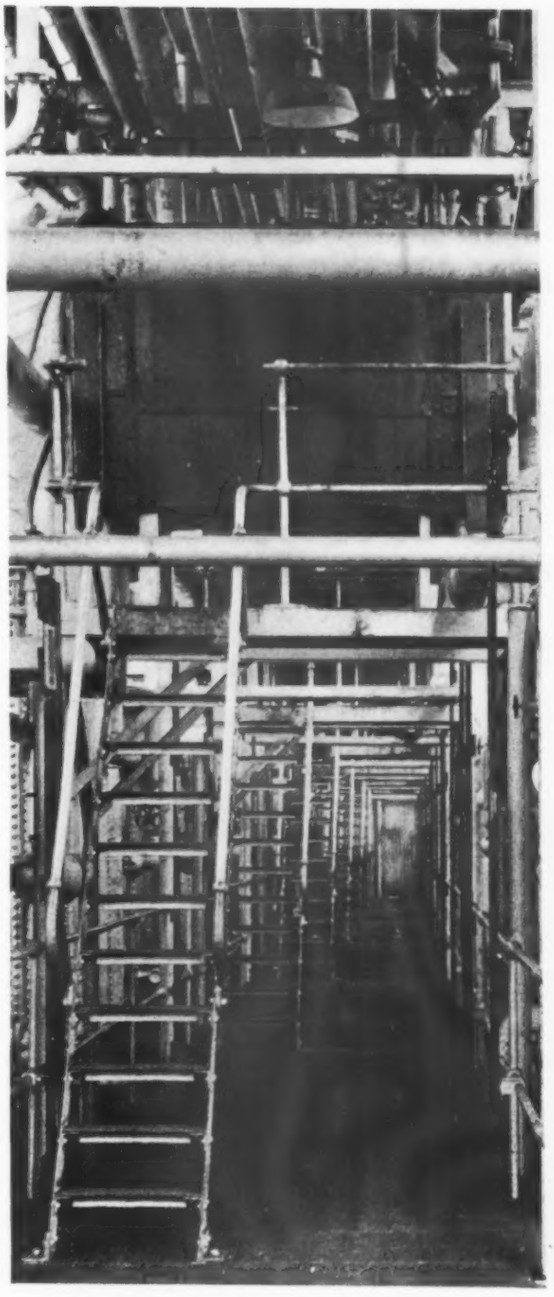
So much for the preparation and blending of lubricating oils. There remains the heavy residue from this lubricating oil distillation, which takes the form of bitumen. This residue can be varied in melting point at will by regulation of temperature, pressure and reflux. Normally, two main grades of bitumen are prepared, the first a low melting point bitumen containing some proportion of the heaviest lubricating oil, which is utilized as the ideal lubricant for the journals of the rolls of tinplate mills in South Wales, and is appropriately called Hot Neck Grease. A further quality of rather higher melting point is the normal material used as the base for the graded bitumens used for road making, while still higher melting point bitumens are prepared and sold for special purposes.

The preparation and collection of these bitumens require some special equipment, and the refinery has recently been provided with gravity-fed overhead settling tanks, into which the hard bitumens are run by gravity to a depth of 12-18 in. and allowed to set, thereafter being broken up and loaded into railway trucks run underneath these trays. The softer bitumens are kept warm in heated reservoirs and run into lagged rail cars or drums for dispatch as required.

These bitumens are also used as the base for certain paints and mastics, while the working up of road bitumens by blending with various cut backs and treating also requires special equipment. The new programme at Llandarcy involves the production of considerably increased quantities of bitumens, and facilities on the above lines are being provided for this larger quantity. The production of wax will also be increased from the present quantities, and increased facilities for the sweating, filtration and subsequent slabbing of wax will also be provided.

To keep pace with these increases and developments, the refinery services in the way of water, steam and electricity supply have had to be augmented; but with the availability of electric power from the grid, at the advantageous prices which have been obtainable on account of the constant nature of the refinery load, it has been possible to plan all these recent extensions without any major increase in either the water or steam supply, and with only the provision of additional sub-stations, transformers, switchgear and mains for the additional power supply.

All these developments have entailed much thought and planning on the part of the technical and development staff. The Llandarcy refinery is at the present time not operated at very large capacity, yet the scope of its operations and the number of products produced are such that every phase of refining activity is covered. The refinery therefore constitutes, in addition to its use as a production and distribution centre, a valuable experimental centre for the company adjacent to headquarters, and a most valuable training ground for technical and operating staff.



Numerous incoming lines run above the central isle to the overhead blending tanks—making possible the production of a wide range of products to different specifications.

Characteristics of STEELS Used in Refineries

By E. C. WRIGHT

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Figure 1: Micro-section of low carbon steel before exposure to high temperature service. Magnification 1,000.

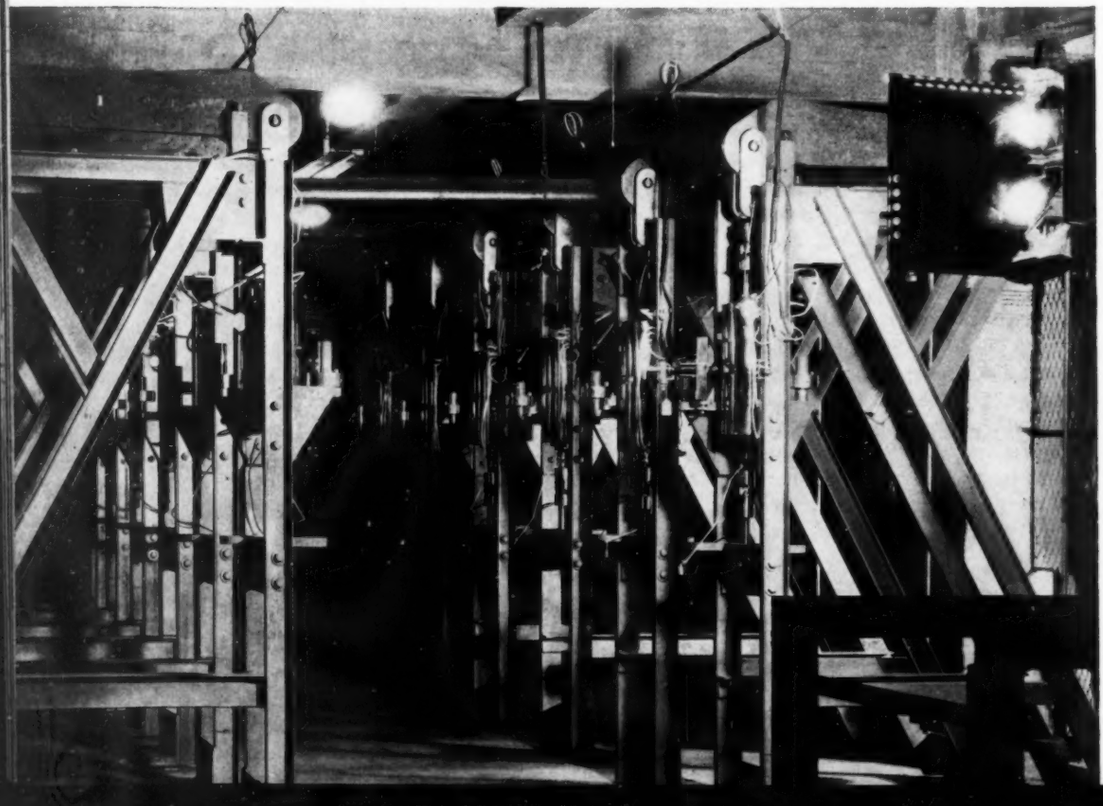
UP TO THE time of the World War the manufacture of gasoline was largely conducted in shell stills. These units operated at low pressures and temperatures and merely fractionated the different constituents in the crude oil. Recoveries of gasoline were low, and the quality of gasoline, with respect to anti-knock properties, was also poor. The improvements in automotive motors and the great increase in the use of automobiles created an enormous demand for more gasoline of a superior quality, and this led to the development of the cracking process. Probably the first large commercial units for actual cracking of hydrocarbon vapors were constructed about 1918 and 1920. These early units were designed and fabricated in accordance with the ordinary steam boiler practice, and many improvements in mechanical design and furnace construction have since been necessary. All of such earlier units were of ordinary low carbon steel, similar to that used in boiler plants.

These first cracking still units were successful, and the growth of the cracking process became very rapid. Many difficulties developed, due not only to poor furnace design but also to such causes as inadequate or unsuitable properties of the steel and defects associated with corrosion. It was early found that some crude oils could be processed in ordinary steel equipment without much difficulty, while other crudes, particularly those high in sulphur, had a rapid deteriorating effect on the tubes and plates from which the apparatus was built. Development of the cracking art also indicated that higher and higher pressures gave superior gasoline and a greater yield of gasoline. Operating temperatures were also gradually increased until, at the present time, temperatures as high as 1200 deg. F. are employed. Since very little steam boiler equipment had been constructed to operate at temperatures above 700 deg. F., refinery engineers in the early stages had to design equipment for pressure stresses at operating temperatures which represented an unexplored field. That such apparatus has been successful constitutes a great achievement for refinery engineers.

In cracking still design it was soon recognized that the properties of steel, based on tests made at room temperature, gave little or no indication of what stress steel could carry at some elevated temperature. At temperatures above about 750 deg. F., which were soon reached in cracking equipment, it was early noted that steel under stress tends to flow, and that every cycle of over-stress caused the steel to take an appreciable permanent set. In cracking coils, the tubes usually swelled to a considerable extent before final rupture took place, and operators became skilled in calipering the inside diameter of tubes to detect those which had expanded to dangerous limits. It was also noticed that steel subjected to a high temperature for a long period, seemed to become softer, and the well known hammer test, which is still used in some refineries, was convenient in detecting old pieces of equipment which had softened in service. Examination of numerous pieces of ruptured material from refineries by metallurgists also showed the softening effect produced in service and demonstrated quite clearly that this was due to a change in the structure of the steel caused by the long exposure to high temperature.

Ordinary low carbon steel as manufactured has a structure made up largely of two constituents. The majority of the steel consists of soft grains of iron, usually termed ferrite and a small amount of iron carbide, which is associated with the iron in the form of minute lamellar plates. This composite constituent is called pearlite. Figure one is a photomicrograph, which is typical of a low carbon steel before exposure to high temperature service. Steel with this structure is usually referred to as being in the normalized state. It has been found from hundreds of examinations of speci-

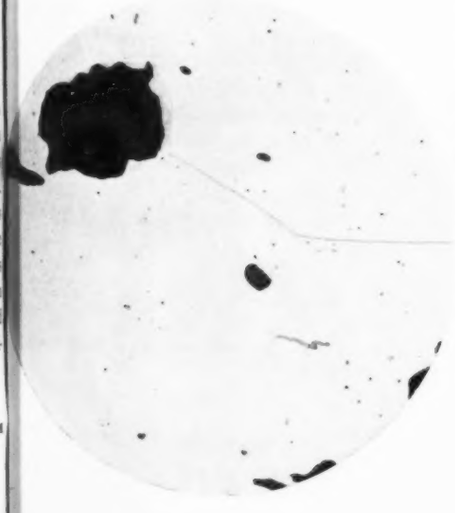
Figure 4: Battery of creep testing machines.



mens taken from high temperature equipment that the structure of the steel gradually changes in such a way as to cause the transformation of the lamellar pearlite into a state where the iron carbide is no longer in the form of plates but coalesces into globular masses, known as massive cementite. Figure 2 illustrates a typical instance of low carbon steel which has been in service for several thousand hours. The structure of the metal in Figure 2 represents steel which is considerably softer and has a somewhat lower tensile strength at high temperatures. The structural change, shown by a comparison of Figures 1 and 2, may progress further, for, in a few cases where steel tubes have been in service for periods of 20,000 to 40,000 hours, the iron carbide is finally completely broken down into ferrite and graphite. In this condition the steel is similar to malleable iron, having a much lower tensile strength than before; and, were it not for the fact that the original steel was quite low in carbon, the effect of this graphite would be even more pronounced. Figure 3 is a photomicrograph of steel taken from an actual tube which had been in service, subject to flame impingement for 30,000 hours. This shows that almost all of the carbide has completely changed over to graphite. Fortunately, this represents a very rare occurrence, as it is seldom that any tube is exposed for such long periods of time to such a high temperature, which, in this case, must have been 1200 deg. to 1300 deg. F. Such changes in structure occur much more rapidly at higher temperatures. In the temperature zone of 900 deg. to 1100 deg. F. the change is very gradual, but it progresses at a rapid rate at temperatures above 1100 deg. F.

The change in structure mentioned above is not readily reproducible in the laboratory, because it requires a long period of exposure to temperature; stress, if sufficiently high, may also be a factor. Tubes in a cracking coil are subjected to internal pressure stress and also to a considerable but unknown stress due to thermal effects. Since cracking still tubes must have a heavy wall to withstand the pressure, and since there must be a considerable thermal gradient through the tube wall, there are in service circumferential or hoop stresses. The stress on the outer surface of a tube is, therefore, often different from the stress on the inner surface. The combination of stresses, together with the exposure of temperature, seems to increase the rate of structural change which occurs in service.

Figure 3: Micro-section of still tube after 30,000 hours' service. Carbides changed to graphite. Magnification 1,000.



The conditions outlined above have led to a realization of the urgent need for a great deal of information on the properties of steel at the temperatures at which refineries now operate. At first this led to a great number of tensile tests made in ordinary tensile testing machines at a series of elevated temperatures. In such tests, which are now referred to as short time, high temperature tensile tests, the test piece is heated by a furnace surrounding it to any desired temperature and then broken in the testing machine while at this temperature. Hundreds of such tests have been run on numerous kinds of steel, but the results obtained in different laboratories varied so much that they could not safely be used in the design of equipment. These tests early indicated, however, that the steel actually becomes measurably plastic at temperatures above about 750 deg. F., so that it flows under a relatively low applied load.

This appearance of appreciable plasticity of steel under load at high temperatures over a long period greatly interested metallurgists. A new form of testing was projected from these observations, and efforts were made to determine what maximum load a piece of steel would sustain for long periods without considerable distortion. This resulted in the development of a testing technique which has come to be known as creep testing. In such tests, a specimen of steel is placed in a furnace and heated to a definite temperature. When uniformly heated, a fixed load is then applied, the load being maintained constant throughout the period of the test. The amount by which the specimen stretches or elongates under this condition is recorded at regular intervals for long periods of time. This elongation is called creep, and, when the rate of elongation reaches a constant value, this can be designated as the creep rate for a given load at a given temperature. Tests of this nature extend over a period of from 500 hours to several thousand hours; it has lately been found that creep tests must be conducted for a period of at least 3,000 hours before the limiting creep load for a given creep rate can be accurately estimated. Even so, all values for creep limit

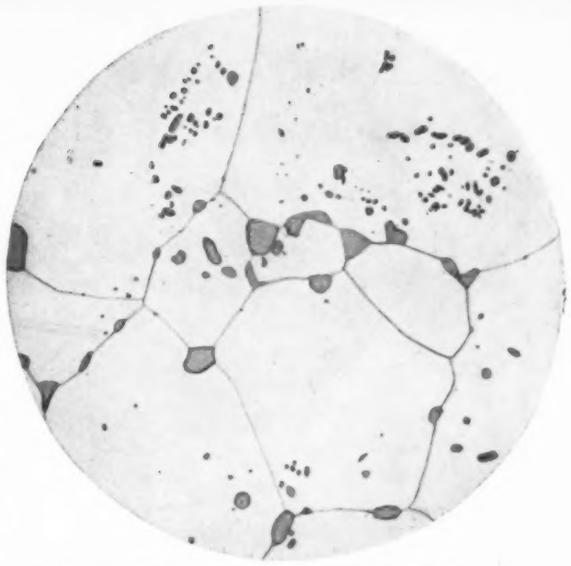


Figure 2: Micro-section of low carbon steel after several thousand hours of service. Carbides in the form of massive Cementite. Magnification 1,000.

are, in a sense, estimates, because it is impossible to predict at what periods during the life of a piece of apparatus the rate of creep may change. In order to arrive at some fairly safe basis, engineers have designated limiting creep loads as those stresses which the material can sustain for periods of 10,000 or 100,000 hours without elongating over one percent. Lately, creep loads have been more conveniently designated as those loads which can be tolerated with creep rates of .01 percent per 1,000 hours or .1 percent per 1,000 hours. The latter figures have more meaning as they represent actual determinations; whereas, very few if any, creep tests have been extended to such periods as 100,000 hours (11.1 years).

The stress values, which have been given to design engineers as limiting creep loads, are quite low, often less than 10 percent of the ordinary strength of the material at room temperature. Naturally, at such low stresses, the use of a large factor of safety, such as 5 to 1 commonly used, is impossible and it is also entirely unnecessary. The reason for this is that the limiting creep load is the load which the metal can sustain for thousands of hours with only very slight deformation, and a total elongation of only one percent per 10,000 hours is an extremely slow rate of flow. An ordinary steel tube will usually expand 25 percent to 30 percent in diameter before rupturing, and this makes it apparent that an elongation of only one percent represents flow at stresses which are ordinarily safe except in high speed machinery where very accurate dimensions must be maintained. For this reason a factor of safety of 1½ times or, at the most, 2 times the limiting creep load at a given temperature has been successfully employed in design.

It will be evident that creep tests require very tedious and prolonged observations.

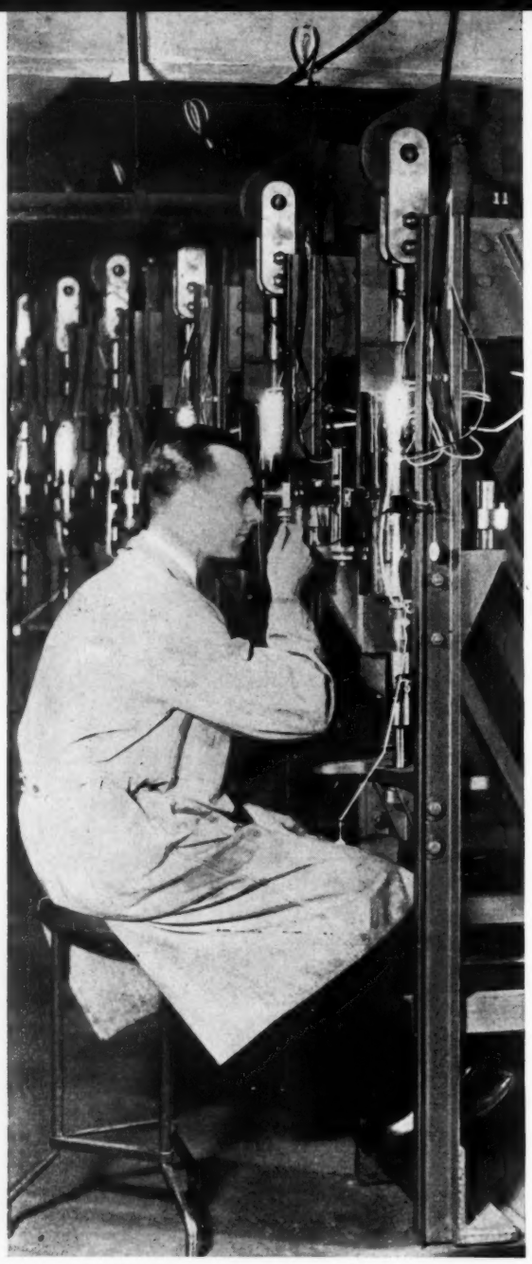


Figure 6: Observer making a reading of elongation.

In addition to this, extreme accuracy has been found to be vital in measuring the small increments of stretch which occur from day to day and also in the constant maintenance of an accurate temperature of the test piece itself throughout the whole period of testing. Variations of even five deg. C. above or below the temperature aimed at may alter very considerably the apparent rate of flow which occurs. These refinements were not early rocognized; as a result, a considerable amount of creep testing, which was conducted at great expense, gave very misleading and conflicting information. In fact, it has only been during the past six or seven years that laboratories throughout the world have resorted to sufficiently precise methods and, even today, there are several points in this procedure which are controversial.

A picture[1] of a typical modern creep testing apparatus is shown in Figure 4. Figure 5 shows auxiliary equipment, which is necessary for the precise control of the temperature of the test specimens. Figure 6 is a close-up view of the creep testing machines with an observer making a reading of the elongation which had occurred over a fixed period of time. These tests proceed 24 hours a day for several thousand hours, and constant supervision, checking and observation is necessary to maintain the precision required if the result is to be reliable. It is little wonder, therefore, that the determination of the creep or plastic properties of all the numerous forms of steel now used in refineries has been so long delayed. It will still be many years before a complete survey of the desired temperature range can be completed on all the steels which are now in use.

The change of structure in steel in refinery equipment, which was earlier described has now been completely verified in long time creep tests. It has been found that creep test specimens under stress at high temperature for a long period undergo the same structural transformations which occur in service. More important, it has been found that the high temperature rigidity of steel decreases as the structural changes take place, and, therefore, a creep test made on a specimen of steel which has the so-called normalized structure will often yield a higher result than if the creep test specimen had been placed in a structural state which finally develops after long periods at high temperatures. In other words, if a creep test is run on a specimen cut from a new still tube in comparison with a specimen cut from a still tube which had been in service for a long time, the creep load as determined for the new tube might be considerably higher than that obtained on the used tube. This would be particularly evident if the creep test itself had been conducted for an insufficient length of time. Creep tests extending over a period of 500 to 1,000 hours do not last long enough to permit the structural changes to progress as far as they do after longer periods of exposure. It has been very well demonstrated that creep tests, if continued for only a short period, may be quite misleading, and that extrapolations of the result of a test, lasting only 500 hours, to a period up to 5,000 to 10,000 hours, are usually quite unsafe. This is particularly true of simple carbon steels. To emphasize this point, Figure 7, which shows a so-called family of creep curves, indicates clearly the effect of time on variation of the creep rate.[2] It will be noted that specimens subjected to high loads show, during the early periods of the test, a very uniform rate of creep which greatly accelerates during the later stages, often resulting in fracture of the specimen. Extrapolation of the creep load from such curves is not safe, although it has been frequently done in the earlier history of creep testing.

The difference in structure illustrated by Figures 1 and 2 indicates quite clearly that the previous heat treatment of a creep test specimen and the length of time of testing have an important bearing on the results obtained. Tests recently completed on low carbon boiler steel and on low carbon steel with .50 percent molybdenum, which is now being used widely, bear out this conclusion quite strikingly. For example: tests conducted at 1,000 deg. F. on low carbon, open hearth killed steel in a normalized state have indicated a limiting creep load for .1 percent stretch per 1,000 hours as high as 6,000 lbs. per sq. in., particularly when the test is not extended beyond 500 hours. Specimens of the same steel, heated to temperatures of 1300 deg. F. (a softening treatment) for long periods before testing, have shown a limiting creep load as low as 4,200 lbs. per sq. in. for .1 percent stretch per 1,000 hours at 1,000 deg. F. Quite similar results have been noted with recent tests at 1,100 deg. F. on low carbon steel containing .50 percent molybdenum[3]. The steel in a normalized state showed good creep resistance up to about 500 hours, but, when the test was extended to 3,000 hours, the creep rate increased markedly. After 3,000 hours, the limiting creep stress for this initially normalized specimen was 2,500 lbs. per sq. in. Another specimen of the same steel, normalized and suitably drawn, showed a creep load as high as 3,500 lbs. after 3,000 hours at 1,100 deg. F. These values clearly show how variation in the prior treatment of the test specimen greatly changes the creep results obtained. It is believed that creep test specimens should be placed in a structural condition, which is similar to that which develops in service, in order that the limiting strength of the material after long service life may be more accurately estimated. This is a vital factor in the design of equipment which is to operate over periods of several years.

One other metallurgical property which profoundly affects the flow of metals is that which is associated with the melting practice used in making the steel. Simple carbon steels can be broadly classified into two distinct types, even though the chemical composition may be identical. One type is

1 U. S. Steel Corporation Research Laboratory.

2 Taken from "On the Influence of Time on the Creep of Steels," by White, Clark and Wilson: proceedings American Society for Testing Materials, Vol. 35, Page 172—1935.

3 Private communication from U. S. Steel Corporation Research Laboratory.

the so-called killed steels, wherein the metal in the ladle is treated with deoxidizing agents, such as silicon, aluminum, etc., to eliminate entirely iron oxide in the metal. This type of steel is used largely for bars, forgings and seamless tubes.

The other type of steel is commonly referred to as open steel, in that the metal in the ladle is not treated with sufficient deoxidizing agents to remove the iron oxide which is dissolved in the metal. This steel is used in considerable quantities for flat rolled products such as plate, strip and often in wire. Although the composition of the two types of steel, as determined by usual chemical analysis, may be identical, it has been found that the killed type of steel has considerably higher creep resistance than the open steel. For example: at 1,000 deg F., whereas for a killed steel the load for a given creep rate may be over 4,000 lbs. per sq. in., it may be less than 2,500 lbs. per sq. in. for an open steel of the same composition. Consequently, low carbon steels used for high temperature service are usually of a killed type, as indicated by a silicon specification in the chemistry. All alloy steels are necessarily made with complete deoxidation, and this distinction is, therefore, not encountered in alloy steels.

Another important feature of the life of steel in refinery equipment is that associated with corrosion. Chemical activity of corroding agents is greatly augmented by high temperature and high pressure, and it is necessary, therefore, in estimating the design and life of the equipment, to take into account the resistance of the steel to corrosion by the materials being processed. At high pressures, the loss of even a small amount of metal thickness by corrosion greatly raises the stress in the steel. There have been numerous tests made in laboratories and at refineries to determine the rate of corrosion under different conditions with different kinds of steel. The results obtained are very conflicting, owing to the fact that there is a wide difference in rate of corrosion, not only in different refineries, but at different locations in the same refinery. Figure 8 is a composite picture of the corrision rate of steels with various chromium contents in four different locations. Some of these tests were conducted in refinery oil streams, while others took place in laboratories. These curves are only generalizations of the average results as reported by several different refineries; they indicate only the trend of what might be expected at any certain location. In these cooperative tests, identical test specimens in different refineries showed corrosion rates varying as much as 100 percent. That this should occur is to be expected, considering the great difference, particularly in sulphur content, between the many different crude oils. Although this work was conducted several years ago, it still is accurate as a means of classifying chromium steels of varying chromium content with respect to resistance to refinery corrosion.

Engineers often ask, "How long will a tube, the wall of which was originally ½ inch thick but has corroded to ⅜ inch thick, last?", and the answer to this is that it becomes a matter of creep rate. For example: if the tube were originally designed to carry a load of one percent in 19,000 hours without corrosion, then, after corrosion, it could operate only either at a lower stress level or for a much shorter period of time. The latter alternative is the natural one and Figure 9 is a different way of presenting creep data which could be employed in considering such a problem. This chart is a plot of stress against time on a logarithmic scale. The line for each type of steel shows the creep load which can be carried for one percent elongation at various periods of time at 1,000 deg. F. In the case of the tube originally of ½ inch wall thickness operating at a fiber stress of 4,000 lbs. per sq. in., which had corroded away to ⅜ inch wall thickness, resulting in a fiber stress of 5,300 lbs. per sq. in. at the same operating pressure, the stress on the tube would then be such that instead of lasting 19,000 hours, its life would be approximately 6,000 hours. If the tube continues to corrode, the increasing stress would indicate a decreasing life.

Another type of corrosion encountered in high temperature service is the oxidation of the steel exposed to the furnace atmosphere. This has become of prime importance as increased temperatures are

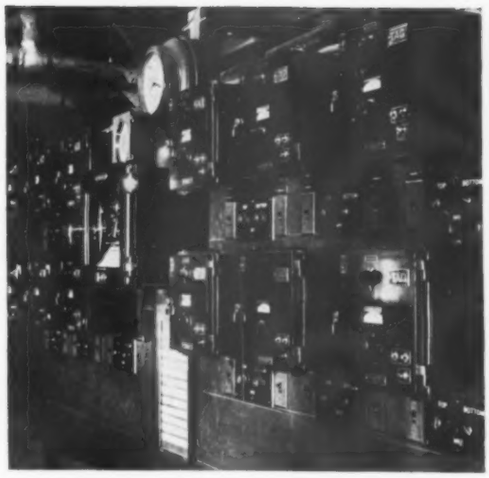


Figure 5: Temperature control equipment for creep testing furnaces.

reached in service. Simple steels begin to scale appreciably at about 1,000 deg. F. and scale quite rapidly at temperatures of 1,200 deg. F. or higher. The surface temperatures of a metal in a furnace may vary within wide limits, particularly on heavy wall tubes on the inside of which an insulating layer of carbon-coke has formed. This is a common situation in still tubes and has led to many premature failures in cracking still coils by reason of the high temperature of the outside of the tube and the consequent rapid oxidation and lowered resistance to stress. Even on clean tubes, the outside surface, which is exposed to high rates of radiation, must be at a higher temperature than the inside surface in contact with the oil. The writer has seen numerous tubes removed from cracking furnaces, of which one side was covered with a heavy gray scale, the other with a soft red scale. Evidently one side of the tube had been exposed to much more severe radiation than the other side. The heavy gray colored scale commonly forms on steel when annealed at temperatures above 1400 deg. F., while the heating of steel to temperatures below this usually produces a soft red scale, resembling iron ore in appearance. The outside skin temperature of tubes with this gray scale must have approached closely to 1400 deg. F. Numerous other cases of cracking still tubes have been observed where the outside surface was covered with a very dense, almost black, scale which forms only at temperatures in the neighborhood of 1600 deg. F. This has been seen particularly adjacent to the hot spot on ruptured tubes; it gives an indication of how severely the material had been locally over-heated before failure.

The rate of oxidation of refinery tubes, therefore, is of considerable interest. At the present time there are at least 15 different

TABLE I—OXIDATION TESTS ON VARIOUS STEELS

	Type of Steel					Scaling Loss (Grams Per Sq. In.)			
Number of Steel	% Chrome	% Manganese	% Silicon	% Molybdenum	% Nickel	at 1200° F	at 1400° F	at 1500° F	Remarks
1		.50				.974	5.510	8.733	Low Carbon Steel
2		.50		.50		1.261	5.402	7.314	
3		.28	1.50	.50		1.040	5.450	7.061	
4	1.25	.50	.75	.50		.860	4.320	6.549	
5	2.00	.50	.50	.50		1.257	4.912	8.452	
6	2.00	.50	1.25	.50		.724	4.578	6.076	
7	3.00	.50	1.25	.50		.043	.149	1.040	
8	5.00	.50	.50	.50		.720	2.408	3.432	
9	5.00	.50	1.50	.50		.003	.052	.081	
10	18.00	.50	.50		8.00	.005	.011	.025	
11	25.00	1.00	.50			.000	.000	.000	

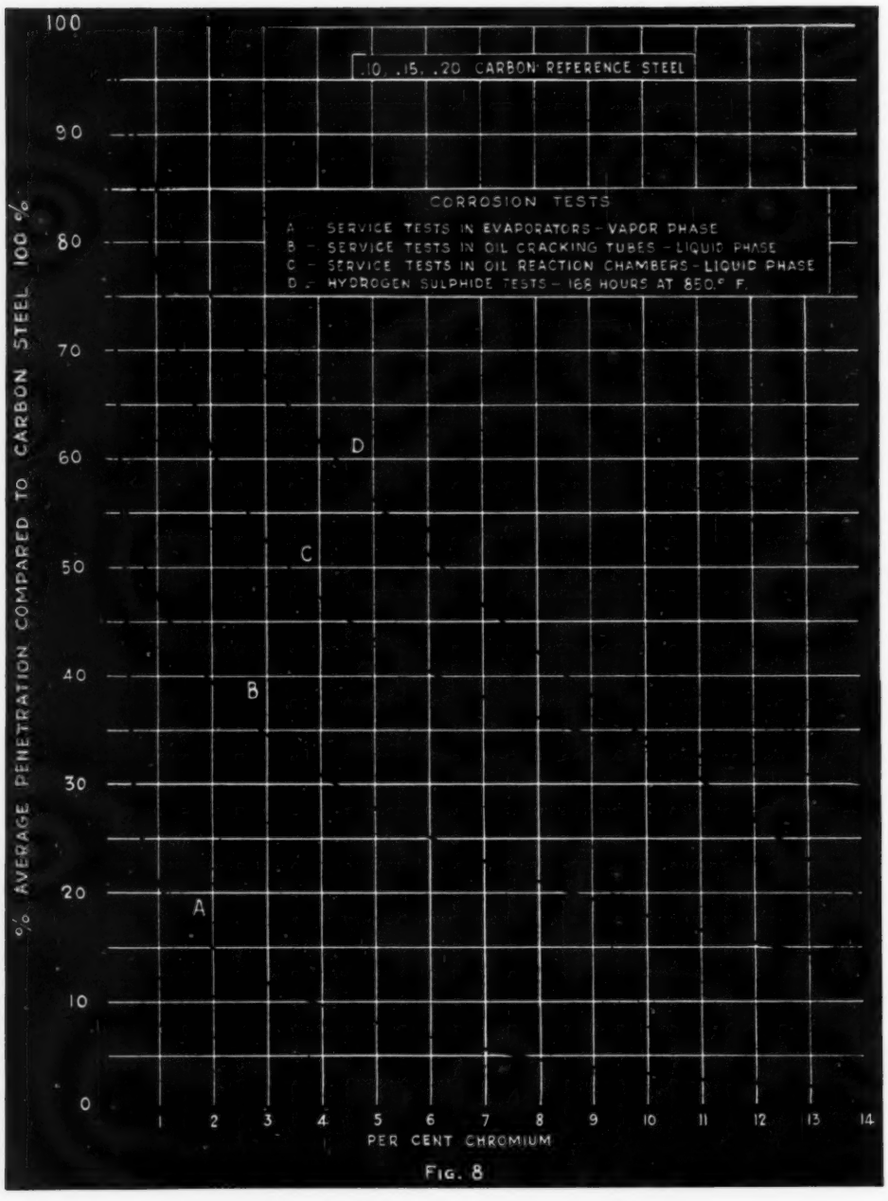

.10 .15 .20 CARBON REFERENCE STEEL
CORROSION TESTS
A - SERVICE TESTS IN EVAPORATORS - VAPOR PHASE
B - SERVICE TESTS IN OIL CRACKING TUBES - LIQUID PHASE
C - SERVICE TESTS IN OIL REACTION CHAMBERS - LIQUID PHASE
D - HYDROGEN SULPHIDE TESTS - 168 HOURS AT 850° F.
% AVERAGE PENETRATION COMPARED TO CARBON STEEL 100 %
PER CENT CHROMIUM
A
B
C
D

FIG. 8

kinds of steels used in practice for hot oil lines and cracking coils. Table I shows the results of tests, just completed on some of these steels in the laboratory, of the rate of oxidation, for these several steels at temperatures of 1200 deg. F. and 1500 deg. F. These tests were conducted in an electric furnace in order to control precisely the temperatures over the long period of time necessary to reach a definite result. The data thus indicate the relative resistance of these steels to oxidation in a current of air at the temperatures given. The rate of oxidation in a refinery furnace is considerably greater, owing to the effect of carbon-dioxide, water vapor and sulphur gases produced by the combustion of fuel. Tests conducted in furnaces with combustion gases indicate the same relative order of oxidation resistance for a given series of steels as tests conducted in a stream of air, but the rate of oxidation is approximately 60 percent greater. One other factor in oxidation is the wide differences in combustion control and temperature control in refinery furnaces, and oxidation tests conducted in cracking still furnaces at different refineries often give apparently contradictory results on this account.

To summarize, refineries require materials which have high strength at elevated temperature, good resistance to the corrosion by sulphur compounds, and high resistance to oxidation. Studies since 1920 have indicated that molybdenum is one of the most effective alloying elements in increasing the creep resistance of steel. Steels containing chromium or chromium and nickel have been found to have the best resistance to sulphur corrosion. The use of chromium, silicon, or aluminum, has also greatly improved resistance to oxidation. As a result of these findings, numerous steels are now available containing these elements, or combinations of these elements, and it seems that in future refinery construction such alloy steels will be largely used. In plants processing non-corrosive crudes some plain steel is still being employed with considerable amount of low carbon steel containing .50 percent molybdenum. A whole range of chromium steels is now available, and it seems apparent that steels with 2 percent to 3 percent chromium will be used for moderately corrosive crudes, and that steels with over 5 percent chromium will be employed where highly corrosive crudes are being processed. Practically all of these chromium steels have additions of molybdenum to improve their strength at high temperature, and lately additions of silicon and aluminum have been made to improve the resistance to oxidation.

The high chromium steels, which are usually termed stainless alloys, have also found an important position in refineries. The commonest type is that containing 18 percent chromium and 8 percent nickel. Tubes made from this alloy have been in service as long as nine years without removal, and, were it not for the higher initial

TABLE II—REFINERY STEELS

TYPE	NOMINAL CHEMICAL COMPOSITION								REMARKS
	% Carbon	% Manganese	% Molybdenum	% Chromium	% Silicon	% Columbium	% Nickel	% Aluminum	
Carbon	.15	.50	.50		.15				Mild Corrosion Condition
Molybdenum	.15	.50	1.00		.15				" " "
	.15	.50	1.50		.15				Moderate Corrosion & Oxidation
Chrome	.10	.50	.50	2.00	.30				" " " "
Molybdenum	.10	.50	.50	3.00	.30				" " " "
	.10	.50	1.00	2.00	.30				Severe Corrosion & Oxidation
	.10	.50	.50	5.00	.30				Non-Hardening Alloy
	.10	.50	.50	5.00	.30	.80			Most Severe Oxidation and
Chrome	.10	.50	.50	2.00	1.25				Moderate Corrosion Conditions
Molybdenum	.10	.50	.50	3.00	1.00			.50	
Silicon	.10	.50	.50	3.00	1.25				Most Severe Oxidation and
	.10	.50	.50	5.00	1.25				Severe Corrosion Conditions
	.10	.50	.50	5.00	1.00			.50	
	.10	.50	1.00	5.00	1.25				For Highest Pressures—Worst
	.06	.50		18.00	.50		8.00		Corrosion & Oxidation
	.06	.50		25.00	.50		20.00		
Stainless	.06	.50		18.00	.50	.75	8.00		Low Pressure—High Temp.
	.10	1.00		27.00	.50			.25 Nitrogen	

cost of this material this alloy would be used in much greater quantity than at present. These steels have the highest strength at high temperature, the highest resistance to corrosion, and very great oxidation resistance, at least up to 1700 deg.F. A high chromium alloy containing from 25 percent to 30 percent chromium has been used for extremely high temperature vapor phase cracking process. This alloy resists elevated temperatures best of all, but has very low creep strength, making it unsuitable for high pressure equipment. It has lately been considerably improved by an addition of nitrogen, which greatly increases the ductility of the material, making for much simpler fabrication. At the present time, there are available a large number of special alloy steels for refinery construction, which are the outcome of cooperation between refineries and metallurgical laboratories in testing factors discussed previously. Table II lists 18 different alloy steels which are now either in wide commercial use or practically ready for manufacture. The steels are conveniently grouped into four classes and reference remarks indicate the suitability of the different compositions for the varying conditions encountered in cracking still service. This whole series of steels is, at the present time, being subjected to creep tests in order to get comparative values of the high temperature creep strength of the several compositions. All of these different analyses are not needed, as probably five typical compositions would be ample for each type of stress and corrosion which exists. The refinery engineer need, therefore, not be confused by such a complicated

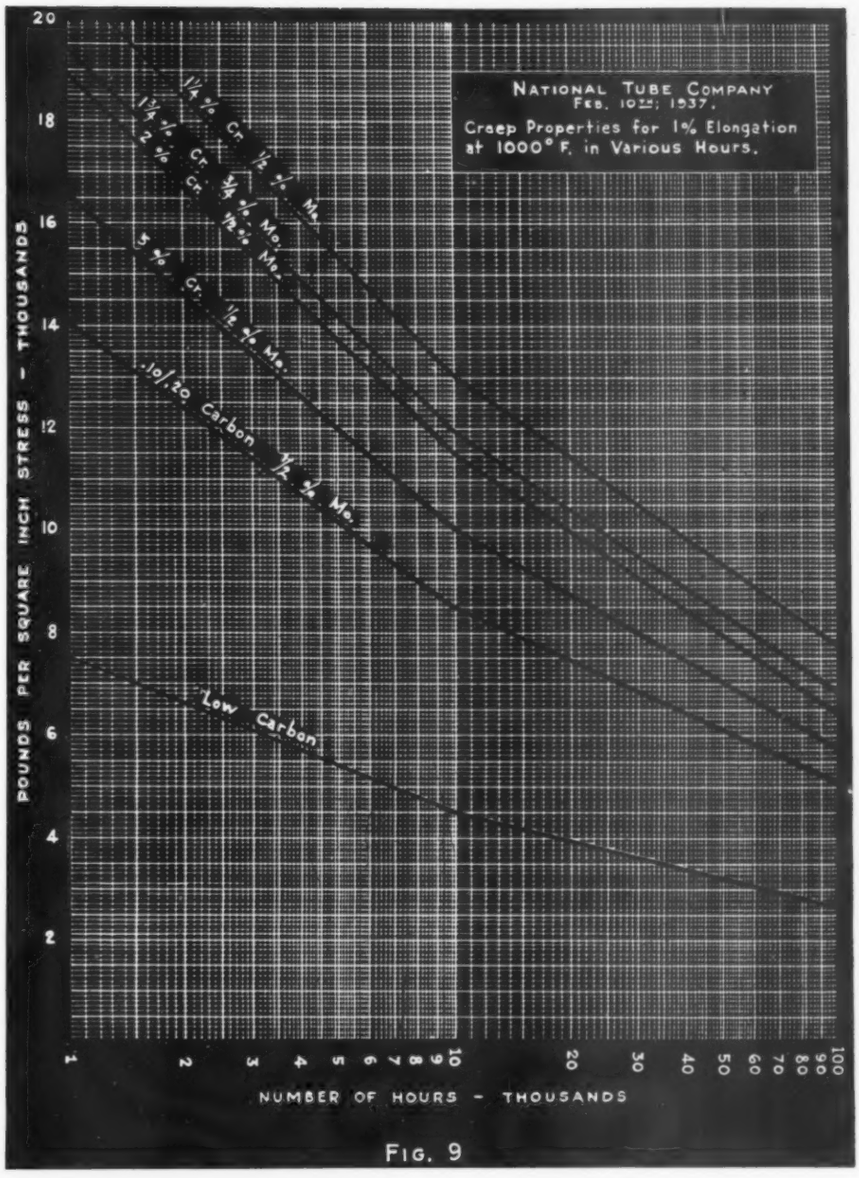

NATIONAL TUBE COMPANY
FEB. 10TH, 1937.
Creep Properties for 1% Elongation at 1000° F. in Various Hours.
1¼ % Cr. ½ % Mo.
2 % Cr. ½ % Mo.
¾ % Cr. ½ % Mo.
5 % Cr. ½ % Mo.
.10/.20 Carbon ½ % Mo.
Low Carbon.
POUNDS PER SQUARE INCH STRESS - THOUSANDS
NUMBER OF HOURS - THOUSANDS

FIG. 9

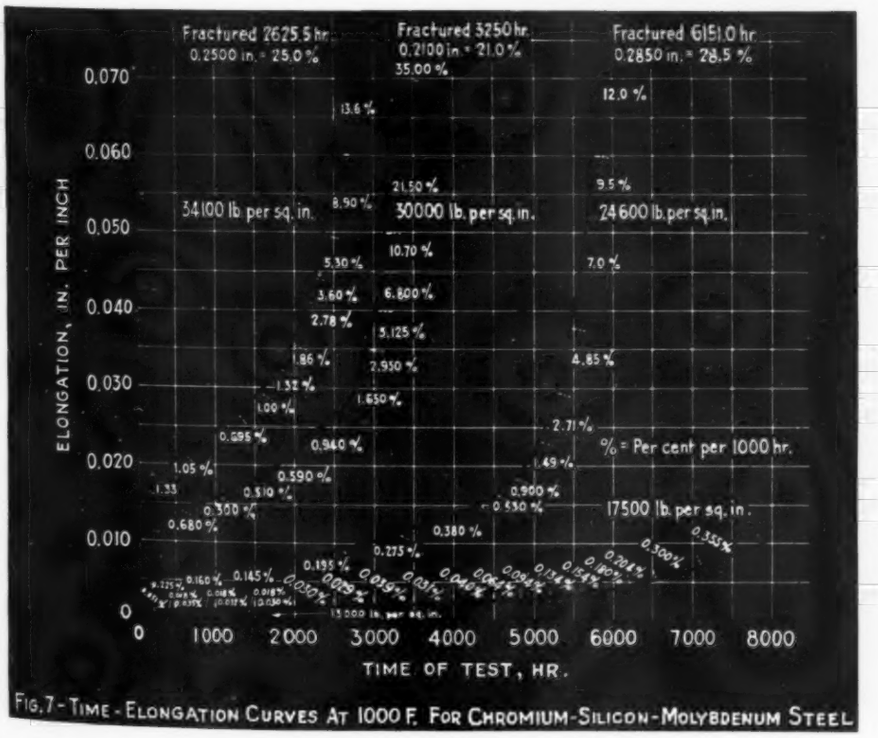

Fractured 2625.5 hr.
0.2500 in. = 25.0 %
Fractured 3250 hr.
0.2100 in. = 21.0 %
Fractured 6151.0 hr.
0.2850 in. = 28.5 %
34100 lb. per sq. in.
30000 lb. per sq. in.
24600 lb. per sq. in.
17500 lb. per sq. in.
% = Per cent per 1000 hr.
ELONGATION, IN. PER INCH
TIME OF TEST, HR.

FIG. 7 - TIME - ELONGATION CURVES AT 1000 F. FOR CHROMIUM-SILICON-MOLYBDENUM STEEL

list of materials, as the alloys included in each group are fairly similar in properties and service life.

The transformation of refinery equipment from simple steels to such complex alloy steels, as given in the table, has given rise to a considerable amount of fabricating difficulty. The ordinary fabricator originally was familiar only with low carbon plate and tube steel, which is easy to form cold, forge and weld into complicated structures. The assembly of this equipment from the alloy steels has presented many problems, but most of these have been very satisfactorily overcome, and it is now possible to obtain almost any refinery part from one or more of the alloy steels which have been included. The fabrication of these steels requires very particular precaution as to welding, heat treating, forming, and it requires skill and experience to handle them to the best advantage.

SHELL HAVEN—A New Type of Solvent Extraction Plant

By Dr. W. J. D. van Dijck and J. S. Oriel, M.C., M.A., B.Sc. M.I.P.T.

A NEW SYSTEM of solvent extraction known as the Rectiflow process is embodied in the lubricating oil plant erected this year at Shell Haven, England, by Shell Refineries, Ltd. The unit, in which furfural is used as a selective solvent, presents some departures from earlier practice in its mechanical features, extraction towers being replaced by mixers and settlers.

Seven stages are used for the counter current extraction of this oil with the solvent and another seven stages for the removal of good oil from the extract solution by a counter current washing with a backwash of refined oil.

In the following article the design of the mixers and settlers is described together with details of the reclamation of the solvent, operating conditions of the plant and analysis of the products obtained.

In the early months of 1937 Shell Refineries Ltd. began the operation of a lubricating extraction plant in their refineries at Shell Haven, England. New ideas regarding extraction methods and new designs of equipment were incorporated in this plant and this fact gives interest to an account of its unique features including a brief explanation of the considerations which led to their adoption.

The plant was designed for the extraction of lubricating fractions of different crudes in order to prepare high quality motor oils. The required capacity of finished raffinate was 900 bbl. per day. The plant was designed to handle waxy as well as non-waxy products and to yield the required quantity of refined oil from intakes from which 25 to 40 percent had to be removed by extraction.

Since the Royal Dutch-Shell group, as a result of its activities in the field of extraction, was in a position to use various extraction methods and solvents, a choice had to be made as to which process and which solvent was the most suitable for the above purpose.

From the very early days of the Edeleanu process the Royal Dutch-Shell group was interested in extraction processes for the refining of petroleum and from collaboration with Edeleanu Gesellschaft resulted in its first Edeleanu plant for kerosene, erected at Balik Papan in November, 1916. The group has since been working on improvements to this process and extending it to materials other than kerosene.

In 1928 Buchel and Saal invented the SO_2-benzene process for the extraction of lubricating oils [1]. This improvement made it possible to use the selective power of SO_2 for the extraction of substances which were insufficiently soluble in SO_2 alone and therefore to extract with this solvent the higher boiling aromatics. Besides SO_2 other solvents were discovered which could be used for oil refining. Thus, for example, Eichwald discovered in 1922 that furfural was an excellent solvent. [2] Later organic nitro compounds and nitriles were shown to be useful selective solvents. [3]

Besides searching for useful solvents, the group was carefully examining methods for operation of these extraction processes. Apart from the old batch process, by which oil was extracted with one or more portions of solvent, continuous processes were developed, using either extraction towers or stages with mixers and settlers. The counterflow process, usually looked upon as the best, enables one to obtain a very pure raffinite with a minimum of solvent, but it cannot yield an extract which is completely stripped of good oil. To improve this point the two-solvent process was invented (1929), in which two solvents, only partly miscible with each other, flow in counter current, while the feed is introduced somewhere in the middle of the system. [4] In this process the raffinite is freed from extract by the action of the first solvent, while the extract is freed from raffinite by the action of the second. This two-solvent method was independently discovered by M. H. Tuttle of Max B. Miller and Co. (1932) who also indicated a very suitable pair of solvents for extracting lubricants, viz. cresylic acid and propane. [5] The well-known Duo-Sol process operates according to the pooled patents and a plant operating on this principle was erected at the group's refinery at Wood River, Ill., in 1935.

This two-solvent process was a definite improvement over the ordinary counter-current extraction process, in so far as it made possible for the first time theoretically complete separation of the components to be separated, thus obtaining the theoretically highest yield of good oil. The two-solvent process, however, is more costly than the simple counter-current process, as not only is the extraction apparatus itself loaded with a large amount of solvent, but also the reclamation of the two solvents called for costly distilling apparatus. It was, therefore, natural that research was directed towards obtaining the advantages of the two-solvent process in a less costly way. The result of this research was the invention of the Rectiflow principle. According to this principle the extract solution is washed with an extract, usually referred to as "backwash", which can be obtained either by cooling the extract solution (1930)[6] or by the removal of solvent (1932)[7]. This Rectiflow process is the true counterpart in extraction of the continuous rectification process in distillation and it effects complete separation of extract and raffinate as successfully as the two-solvent process does.

The theory of this process was given by Saal and Van Dijck at the World Petroleum Congress in 1933[8]. The Rectiflow process, although less costly than the two-solvent process, is nevertheless still more costly than a simple counter-current process as usually applied, since not only more stages or higher towers are necessary, but also more solvent is needed, owing to solvent being required for the formation of the backwash. These extra costs are met however, by the the higher yield, especially for those crudes which do not contain large percentages of high class lubricating oils or those in which the separation of high class oil from oil of moderate quality is difficult. During research on this process the great importance of applying the right temperature at any point of the extraction process became apparent, as selectivity decreases rapidly with increasing temperature, while on the other hand the solvent power increases with increasing temperature. As neither great solvent power without selectivity, nor great selectivity without

Figure I—Rectiflow pilot plant at the Royal Dutch-Shell research laboratory in Amsterdam.

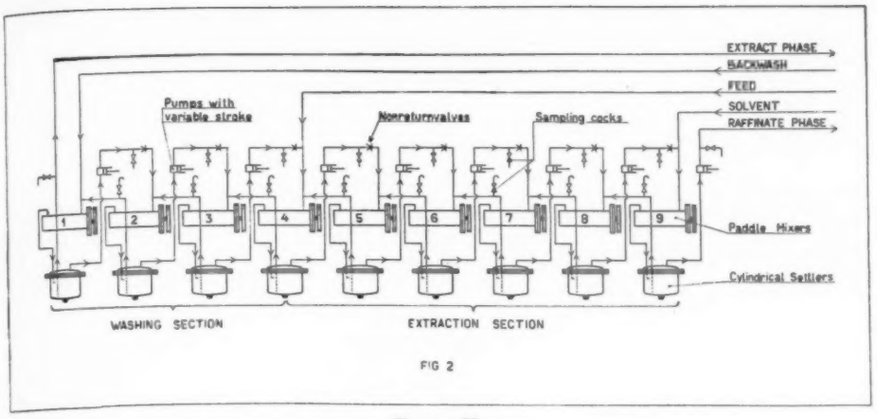


Figure II.

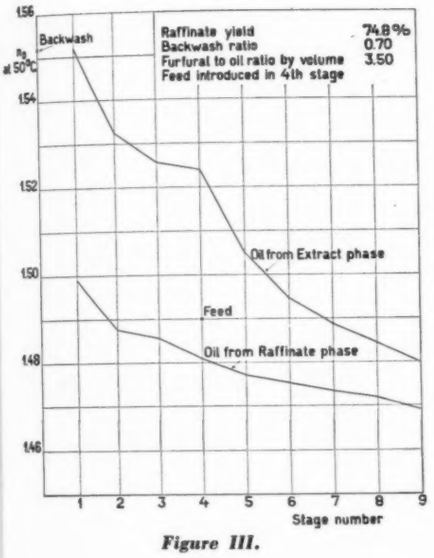


Figure III.

solvent power is of any technical use it is obviously important to extract at the right temperature and to obtain maximum effect a temperature gradient should be maintained along the extraction system.

The choice of the most suitable solvent was the next consideration.

When comparing the different solvents, attention has to be paid in addition to selectivity and solvent power, to their stability, the possibility of easy reclamation, their corrosive properties, their toxicity and their price.

As the plant had to work also on waxy oils it was necessary to use a solvent which would have a good selectivity at relatively high temperatures. Working at high temperatures has the advantage also that the oil in process has a low viscosity, which facilitates mixing, exchange and settling. On these grounds furfural was chosen as the selective solvent.

In order to find the most suitable operating conditions for the Rectiflow plant and to examine the products obtainable, a pilot plant was first installed in the research laboratory at Amsterdam. (illustrated in Figure I). This pilot plant had a capacity of one litre per hour intake and consisted of nine stages, each stage comprising a mechanical mixer and a settling tank, in which the emulsion made in the mixer was separated into two layers. Each combination of a mixer and a settler was submerged in an oil bath, which was thermostatically controlled so as to maintain the right temperature. The transport of the phases to the adjacent stages was done by means of small reciprocal pumps with variable stroke. In order to control the levels in the settling tanks, level indicators were provided, which worked on the difference in the electric conductivity of the two layers. Six stages were used for the extraction section, in which the raffinate was freed from the bad constituents by furfural, and three stages were used for the washing section, in which the extract was freed from any good oil by a backwash of extract. The raffinate phase and the extract phase were continuously led to vacuum distillation towers, in which they were freed from the solvent.

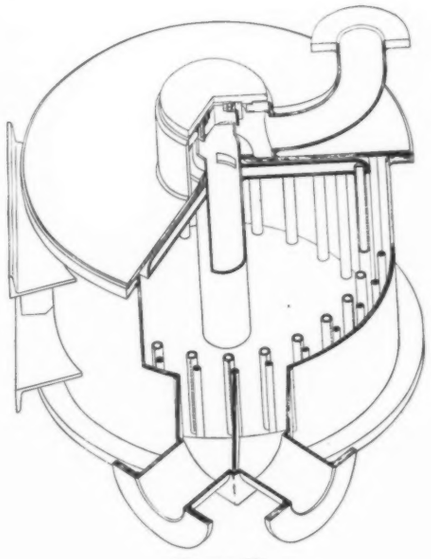


Figure IV.

Figure I shows the stages and the control panels, and the three measuring tanks for feed solvent and backwash, while Figure II gives a schematic flow sheet of the plant, omitting, however, the solvent reclamation units.

To show the effect of the extraction at different stages the refractive indices of the raffinate and the extract at each stage were determined by taking samples and removing solvent. The results are given together with the properties of the feed in Figure III.

In the case of a waxy oil the oil layer from the washing stage after the feed is still definitely waxy. The oil of the second washing stage already shows much less wax, while that of the third stage shows hardly any wax at all. Thus the pilot plant definitely demonstrates the effect of the Rectiflow method.

The next consideration in the design of the commercial plant was whether extraction towers or extraction stages should

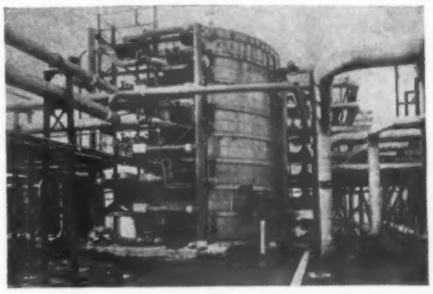


Figure V—Setting apparatus at Shell Haven consists of seven units on top of each other.

be used. Extraction towers are relatively simple to operate, as pumps to transport the layers from stage to stage are superfluous. They have, however, the disadvantage that there is no control on the size of the droplets or on the exchange and that they tend to channel, i.e. that certain amounts of the phases pass each other without coming into intimate contact. Various experiments on a pilot plant scale showed that the compromise between intimate mixing and good settling in a tower is poor.

A very serious point to the disadvantage of the tower is further that it is very difficult to realize the right temperature gradient necessary for optimum extraction. Although it is possible to make a temperature gradient by introducing the solvent at a high temperature and the feed and backwash at lower temperatures, the temperature gradient which is reached in this way is not the optimum.

The introduction of coolers in extraction towers is impracticable, as the cooling surface necessary in towers must be extremely large because of the low velocities and therefore the low heat transfer coefficients in the tower and moreover thermal

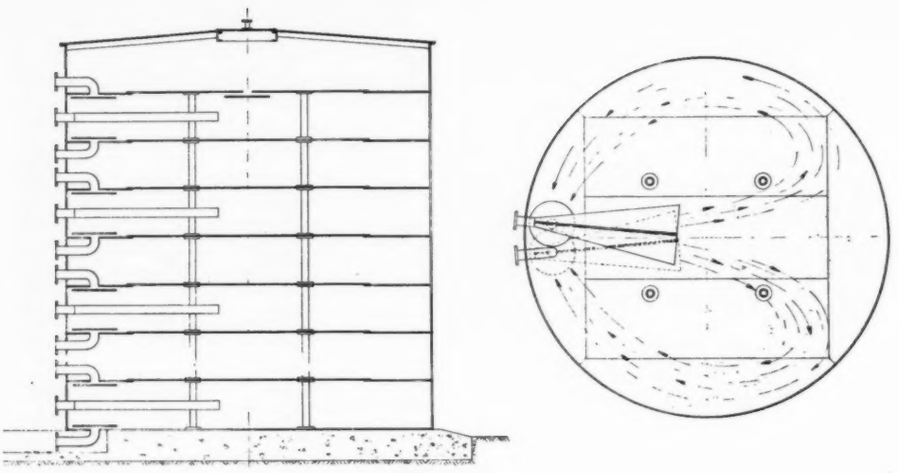


Figure VI.

circulation would be set up. Removing the liquid from the tower to outside coolers and redistributing the liquids at the appropriate temperature in the tower practically reduces the tower to a set of mixers and settlers.

As the object of the plant at Shell Haven was to determine what results could be obtained with the best apparatus from a theoretical standpoint and at the same time to give the plant the greatest possible flexibility, it was decided to use mixers and settlers instead of towers. In this respect it was considered that normal development in plant construction is a slow process, in which step by step improvements are made, mostly on practical grounds, so that it was thought useful to erect on this occasion a plant which might be too good and therefore too costly, but which would show the definite limits obtainable, so as to enable us in future to make a better compromise between the theoretically possible and the simplest and cheapest designs.

Once mixers and settlers had been decided upon, their design had to be considered.

The purpose of the mixer is threefold: (1) it should mix the two phases in such a way that the material to be dispersed is evenly distributed over the other phase; (2) it should disperse that liquid in sufficiently fine droplets to ensure sufficient exchange between the two phases, and (3) it should avoid the formation of too fine an emulsion, which would interfere with good settling. As the size of the droplets is dependent on the interfacial tension between the two phases, which will be variable for different intakes, and furthermore as the size of the droplets necessary for good exchange will differ according to molecular size and viscosity, to obtain the maximum effect for various oils it is necessary to set the mixer in accordance with the requirements of the oil. Mechanically driven mixers were thought to be the most suitable type.

Its working element is a rotating case, consisting of perforated tubes with holes in the outside, from which flows the oil which has to be dispersed. The mixers are belt-driven from a common shaft, with step pulleys to allow for variation of the number of revolutions. (See Figure IV).

We come now to the construction of the settlers. In principle there are two possibilities: either settling by gravitation or separation by centrifuges. The first was chosen as being more reliable and less expensive. Much care was given to the form of the flow of the liquid in the settling zone. Unnecessary turbulence should be avoided, while a certain degree of movement is useful for a better coalescence of the particles. Figure V shows the construction of the settling apparatus, seven settling units were built one on top of the other and from a single tank.

These settling units are 6.5 metres in diameter and the arrangement of the inlet and outlets and the flow in the settlers is shown in Figure VI. Figures VII and VIII show how these inlet and outlets are coupled up to each section. Both from the sketch and the photograph it will be seen that at each stage the delivery from the pump and the suction from the stage above are interconnected. The reason for this is that the flat plates forming the floor of each section have not been made strong enough to stand the weight of the liquid in that section and in the sections above it and therefore means have been provided to

Figure VIII—Inlets and outlets to a section of the settling apparatus.

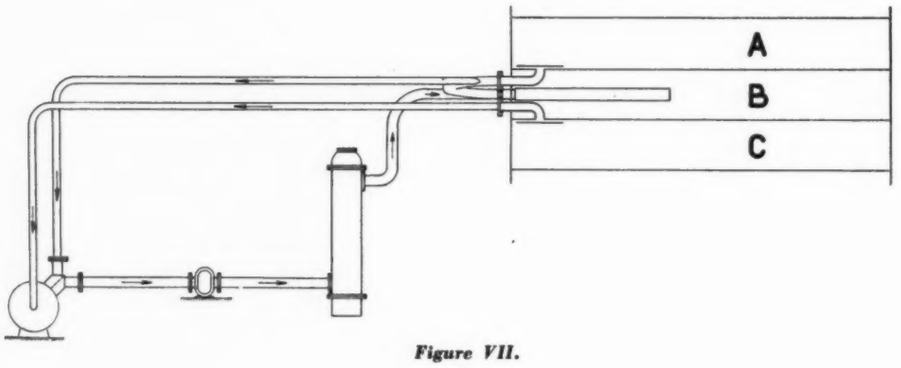


Figure VII.

allow the liquid to pour right through the whole seven stages if necessary, without causing any undue strain.

The arrangements for withdrawing extract and raffinate layers and mixing them are best seen by considering one stage only. In Figure VII we have shown three stages, A, B and C. The extract phase is withdrawn from the bottom of stage A and the raffinate phase from the top of stage C and both are led to the mixer of stage B. From the mixer the emulsion flows into a pump from which the material is delivered through a heat exchanger into compart-

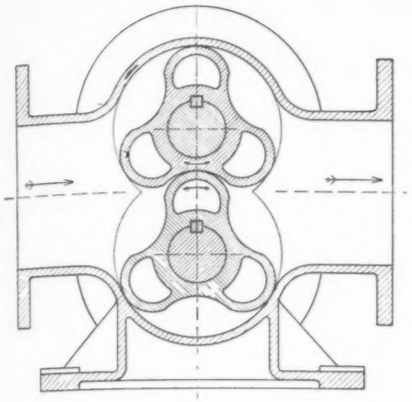


Figure IX.

ment B. The pump has been specially selected so as to prevent any shearing of the droplets and hence any formation of fine emulsion which would be difficult to break in compartment B. The diagram of this pump is given in Figure IX. As the temperature of the stages has to decrease in the direction from raffinate to extract heat must be withdrawn from the mixture. This cooling of the mixture is done by means of cold extract solution returning from the last section of the extraction plant, and by this means a temperature gradient of about 130/40 deg. C. can be maintained.

The levels in each section are observed as in the pilot plant by electrical means, using electrodes placed vertically above one another at a distance of 5 cms. apart. These electrodes are connected to neon lamps and the change in resistance between the raffinate layer and the extract layer shows up clearly by the lighting or otherwise of these lamps. This method is considerably better than sight glasses or floats, as in these cases it is extremely difficult to distinguish between a furfural emulsion rich in oil and an oil emulsion rich in furfural.

There are two settling tanks of seven compartments each. One of these tanks serves to carry out the extraction and the other the washing with reflux (backwash). The number of extraction stages can be readily altered, however, by changing the point at which the raw oil is admitted. The furfural is admitted at the top of the extraction tank and the raffinate layer is taken off from the top of the same compartment. The extract phase is withdrawn at the bottom of the washing tank and backwash admitted there.

It may be explained here why so much care was devoted to the construction of the mixers and the settlers. In practice there is a general feeling that intimate mixing can be obtained with much simpler devices and that as a result of the ready coalescence of the fine droplets of oil dispersed in furfural settling is a relatively simple matter. It is true that in case this coalescence does actually take place readily the mixing apparatus and the settling apparatus can be made both simpler and smaller, especially when between these apparatuses a special vessel giving maximum speed of coalescence is interposed,

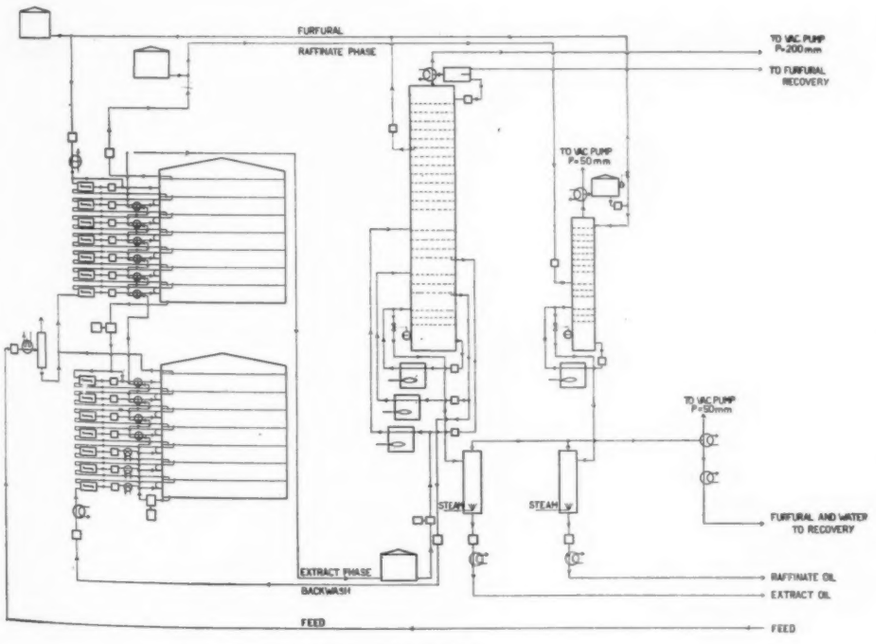


Figure X.

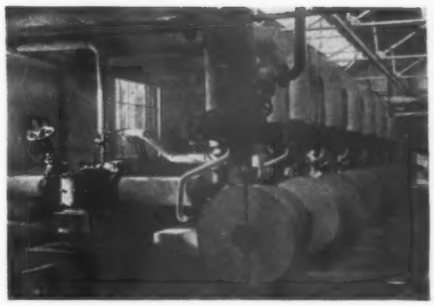


Figure XI—Mixers in the pump house at the Shell Haven solvent plant.

but we must bear in mind that with such an arrangement one is gambling a good coalescence, which might be imparted by small traces of emulsion stabilizing substances. As a shut down of the plant for only a relatively small number of days will cause a greater loss than the saving in mixers and settlers it is advisable to keep on the safe side and to design the mixers and settlers in such a way that, even without ready coalescence, a good exchange and a clean separation between the two phases can be obtained.

The recovery of furfural also presented some problems. The flow sheet (Figure X) shows the general layout of the plant, for which the main desiderata were (a) a clean separation of furfural from raffinate even when extracting light lube oil distillates; (b) a clean separation of furfural from extract; (c) distillation at as low a temperature as possible; (d) as complete a separation of water as possible. The reason for (a) is quite obvious. In addition to the necessity for recovering as much furfural as possible, so as to avoid loss, it is of the utmost importance (b) that no extract remain in the furfural to be returned to the extraction plant and mixed with the ultimate raffinate oil, thus spoiling it. The recovering of the furfural is therefore carried out in rectifying towers, using an ample number of plates. High temperature distillation of furfural (c) tends to produce pyromucic acid and acetic acid. Apart from the loss of furfural involved, the formation of these acids causes considerable corrosion of the plant. As any water contained in the intake is extracted by the furfural and furthermore the last traces of furfural are removed from the oil in a steaming column, it is obviously necessary (d) to remove this water, avoiding any loss of furfural.

The question whether evaporation using the so-called double effect principle is advantageous was carefully examined and various schemes for applying this principle were considered. The principle does not give a cheaper construction, because against the smaller furnaces there are the greater

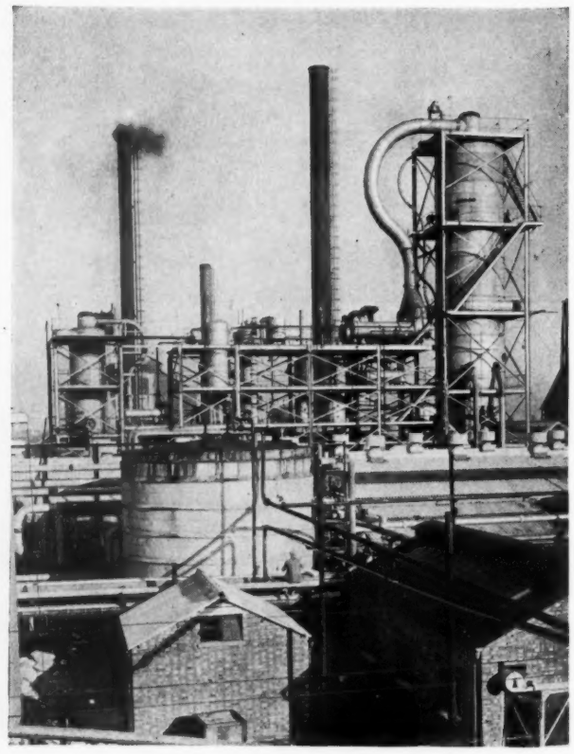


Figure XII—General View of Shell Haven solvent extraction plant.

heating surfaces in heat exchangers, but it allows a reasonable saving in heat input. However, since the maximum temperature to which the furfural has to be heated is higher when using the double effect principle, giving a greater possibility for decomposition and reaction of the furfural with components of the extract, it was decided not to apply the double effect principle.

The extract column has been designed to run at as low a vacuum as is consistent with reasonable construction design. The pressure in this column is 200 mms. Hg., but even so the column is 4.25 meters in diameter. From the flow sheet it will be apparent that a considerable amount of recycling has been arranged in order to avoid high temperatures. All this is consistent with earlier remarks in the description of the plant, where it was pointed out that this plant was designed to show what the theoretically best arrangement could produce.

From the raffinate layer the furfural is also reclaimed in a rectifying tower 1.25 m. in diameter, this tower running at 50 mm. Hg. pressure, so as to ensure that no polymerization of furfural takes place, which would result in these polymerization products concentrating in the final raffinate.

Both from extract and raffinate the last traces of furfural are stripped off in steam strippers provided with several plates so as to save on steam and the consequent necessity for elaborate apparatus for the removal of water.

The provision of a blanket of inert gas for protecting the furfural against oxidation has not been found necessary, but means are provided for the de-aeration of the feed oil.

Figure XI shows the mixers in the pump house, while Figure XII gives a general view of the plant.

Conditions Under Which Plant Has Operated Successfully

Feed	10 vol. tons per hour (1 vol. ton = 1.016 m3)
Furfural	29 " " " "
Backwash	1.6 " " " "
Temperature gradient	117°C to 65°C.
Yield of raffinate	76 vol. %

Analysis of Intake and Products

	Intake 100 vol. %	Raffinate 76 vol. %	Extract. 24 vol. %
Spec. Grav. at 60°F.	0.9125	0.885	1.005
Flash Pt. (P.M.) Closed	445°F	430	425
" Open	475°F	455	455
Visc. Red. 1 at 70°F.			
" 140 "	167 secs	121	900
" 200 "	58 "	52	160
Kin. Visc. at 100 "		74.0	1976
" 160 "	26.2		
" 210 "	11.65	10.07	31.45
Kin. VI.	90	122	—50
Pour point ASTM °F.	110	115	35
Acid Value mg. KOH/grm	0.1	0.014	0.028
Color Union	N plus X	M – X	
Color ASTM	4½ X	4 X	
Refractive Index 50°C.	1.4920	1.4685	1.5575

X diluted 86 vol. white spirit. 13 vol. oil.

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LOW COST Removal of Hydrogen Sulphide from Petroleum Gases

THE ADVENT of polymerization processes has made the separation of hydrogen sulphide from gas mixtures extremely important to petroleum refiners.

Polymerization, believed by many to be the most valuable contribution of chemical science to American industry during the past decade, converts a practically useless or even harmful product into high grade motor fuel. The unique and valuable properties of this new product are now well recognized.

Several polymerization processes have been developed and their successful commercial application demonstrated. It has been found, however, that in building up larger molecules from smaller ones such processes also build up organic sulphur compounds if hydrogen sulphide is present in the gas being treated. Because these sulphur compounds must be removed and since their removal by treatment of the polymer product lowers its octane number and reduces its blending value, separation of the hydrogen sulphide from the gas before polymerization is highly desirable.

A number of processes have been proposed and used for removing hydrogen sulphide from gases. The classic iron oxide boxes are still in use in many gas factories, at natural gas plants and at natural gas pumping stations. In some cases these combersome appliances have been replaced by one or another alkaline absorbing tower. The difficulty with most liquid absorbents has been with regenerating the spent liquor, but this difficulty has now been overcome by two notable improvements.

One of these is the Koppers Phenolate process, developed and patented by the Koppers Company, by which it is stated that more than 95 percent of hydrogen sulphide can be recovered at a cost which may be as low as $3 per ton under favorable conditions of H_2S concentration and gas pressure. Three plants embodying this process are now in operation in the United States.

First of these was built by Koppers Company at El Segundo near Los Angeles, California, for the Standard Oil Company of California. It was put in operation in August, 1936. It processes 16,600,000 cu.

(Continued on page 170)

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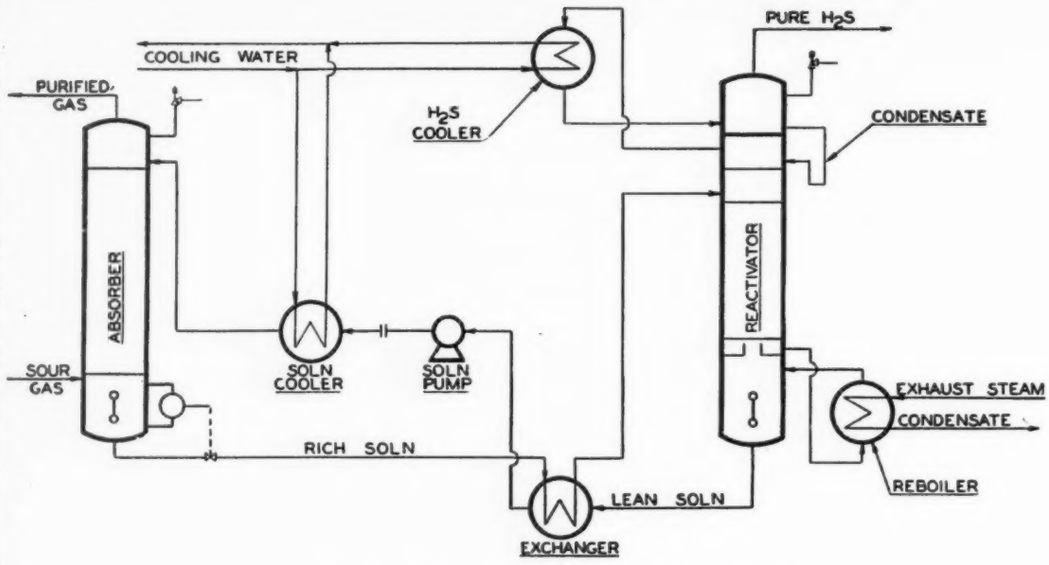

Flow diagram of the Girbotol process.

HYDROGEN SULPHIDE REMOVAL

(Continued from page 168)

ft. of refinery gas per day, removing approximately 40 tons per day of 98 per cent H_2S gas, which is converted into sulphuric acid.

A second plant was completed in July this year at the Philadelphia refinery of the Atlantic Refining Company. Hydrogen sulphide will be recovered from 22,000,000 cu. ft. a day of refinery still gas. Koppers Company also has just completed a similar type of plant to purify natural gas at Wayne, W. Va., for the Chartiers Oil Company. It has a capacity of 5,000,000 cu. ft. a day.

The purification system consists of an absorption stage and an actification stage, through which the phenolate solution is circulated continuously. This solution has an extremely high carrying capacity for hydrogen-sulphide, and as a result, it is necessary to circulate only five to ten gallons of solution per thousand cubic feet of sour gas. This very low circulation rate is one of the reasons for the low operating expense.

The hydrogen-sulphide laden gas enters the absorber at the base, passes up through the bubble-cap trays and leaves at the top, stripped of 95 percent or more of its hydrogen-sulphide. The solution leaving the bottom of the absorber, saturated with hydrogen-sulphide with respect to the incoming gas, passes through the heat-exchanger tubes to the top tray of the actifier. It flows down over the actifier trays, counter-currently to the stripping steam which is generated in the reboiler at the base. Sufficient indirect steam is used to effect the desired degree of actification of the solution. This, in turn, is determined by the maximum residual hydrogen-sulphide desired in the exit gas.

The actified solution flows from the reboiler through the heat-exchanger shell, is further cooled in the solution cooler, and is then pumped to the fourth tray below the top of the absorber. The absorption cycle starts again at this point.

Hydrogen-sulphide laden steam passes from the top of the actifier to the dephlegmator shell and thence the hydrogen-sulphide is forced, by the actifier pressure, to the acid plant burner or other point of disposal. Condensate from the dephlegmator returns to the actifying column.

Fresh water is added continuously to the top tray of the absorber. The three top trays comprise, in effect, a water scrubber to recover chemicals, which have been entrained or evaporated from the solution. It is necessary, at periods of several days, to replenish chemicals, and a small mixing tank is provided for this purpose. The caustic soda and crude phenol used in the process are inexpensive and are commonly used commodities which are readily available on the open market.

This system is completely adaptable to a wide variation in conditions such as hydrogen sulphide concentration, pressure and composition of the gas to be treated.

Another recent process originated and patented by the Processes Division of Girbotol process. In this the scrubbing liquid is a water solution of an aliphatic amine. The amines are relatively non-volatile, alkaline compounds which react rapidly with hydrogen sulphide. The reaction during absorption is a chemical one between an acidic gas and a basic liquid. When the scrubbing liquid containing hydrogen sulphide is heated in the reactivator the chemical bond is broken and the hydrogen sulphide is driven from solution in pure, concentrated form. The amine, being non-volatile, remains in solution, unaltered, ready for reaction with more hydrogen sulphide during its next contact in the absorber.

In one of the large installations of this process, hydrogen sulphide is stripped from natural gas so completely that the purified gas contains less than 1 grain of hydrogen sulphide per hundred cubic feet of gas (0.0017 percent). Such a high degree of sulphur removal is not required in most refineries, but efficient purification is desirable in polymerization because the sulphur content of the polymer product appears to be proportional to the sulphur content of the feed to the plant.

Absorbents used in the Girbotol process are inexpensive and readily avilable. They are stable and losses are small. Steam for heating is the largest item of cost. Low pressure steam is suitable for regeneration or if none is available the liquid pumps may be steam driven and the exhaust used for heating. Cooling water is the only other utility required.

Wide use is being made of the process for purifying sour natural gas. Many sour gas fields lie near consuming areas or are adjacent to distribution lines. As produced such gas is of practically no value and is suitable only for carbon black manufacture. When purified it can be made available for domestic and industrial consumption and in many cases the purification cost is less than the cost of transporting sweet gas from more distant fields. The economic value of this low cost purification process is indicated by the fact that it converts what could almost be termed a waste product into a usable fuel.

Hydrogen sulphide recovered by the Girbotol process may be converted into sulphuric acid in existing or in new acid plants. It may be converted into elementary sulphur or into sodium or ammonium sulphide. Other methods for its utilization have been proposed. It is an extremely powerful reducing agent.

In addition to scrubbing hydrogen sulphide from gases the process is useful for the removal and recovery of carbon dioxide in certain instances. Large quantities of carbon dioxide are recovered by the process for the production of liquid carbon dioxide and dry ice. The process is employed for scrubbing carbon dioxide from industrial hydrogen produced by cracking methane. The process is also useful for CO_2 removal from inert atmospheres.

RUSSIAN REFINING

(Continued from page 149)

considered American experience in analogous plants at Lawrenceville and Port Arthur, the flow chart was revised to include vertical columns under continuous counter flow of the extract. The installation consists of the extraction and regeneration divisions. The proportion of furfural is 150 percent by volume and 190 percent by weight; yield of raffinate is 80 percent and of extract 20 percent.

Distillate from the raw material tank is pumped to heat exchangers where it is heated to 75 or 80 deg. C. by the regenerated furfural, which enters the exchanger at about 160 deg. C. The heated distillate rises to the top of the tower and the furfural flows to the bottom, at a temperature of 110 deg. C. In the tower, which is a vertical cylinder of five superimposed parts, the distillate makes intimate contact with the solvent. The raffinate-solvent mixture is brought from the top of the tower to an intermediate tank at 100 deg. C., while the extract from the bottom at 75 deg., containing 90 percent furfural, flows to heat exchangers and to a settling tank. The raffinate solution flows through heat exchangers to a furnace where it is heated to 200 deg. C., and then goes to the raffinate tower operating under atmospheric pressure in the presence of steam. Furfural vapors are led from the top of the tower, which is sprayed with waterfree furfural, to condensers and immersed coolers. Part of the extract, less oil soluble in furfural, cooled to 40 deg. C., is taken by pumps and goes again to the extraction with fresh input.

The regeneration system consists of a two-flow furnace, steam distillate heat exchangers and two towers—one furfural and one extract tower. Centrifugal units pump the extract from storage through steam distillate heat exchangers. It is then received by the furnace pumps to be heated by one flow through the furnace to 230 deg. C., at which temperature it arrives at the furfural tower. Recycling (tower-furnace-tower) effects a reduction of about 50 percent of total input of extract solution. The balance from the furfural tower is heated by a second flow through the furnace to 230 deg. C., at which temperature it is brought to the upper part of the extract tower, where a similar system of recycling tower-furnace-tower is undergone at 145 percent of quantity in ratio to the input extract solution. Practically all furfural is evaporated in the upper part of the tower, and the residual furfural is removed from the extract by stripping at the bottom. Vapors from the waterfree

(Continued on page 173)

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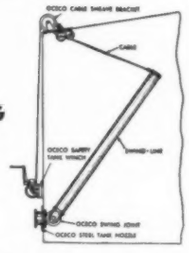

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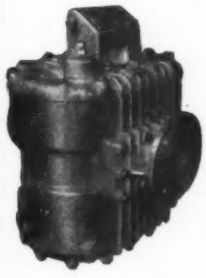

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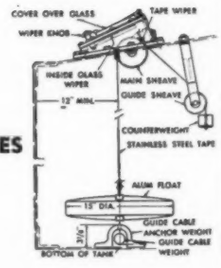

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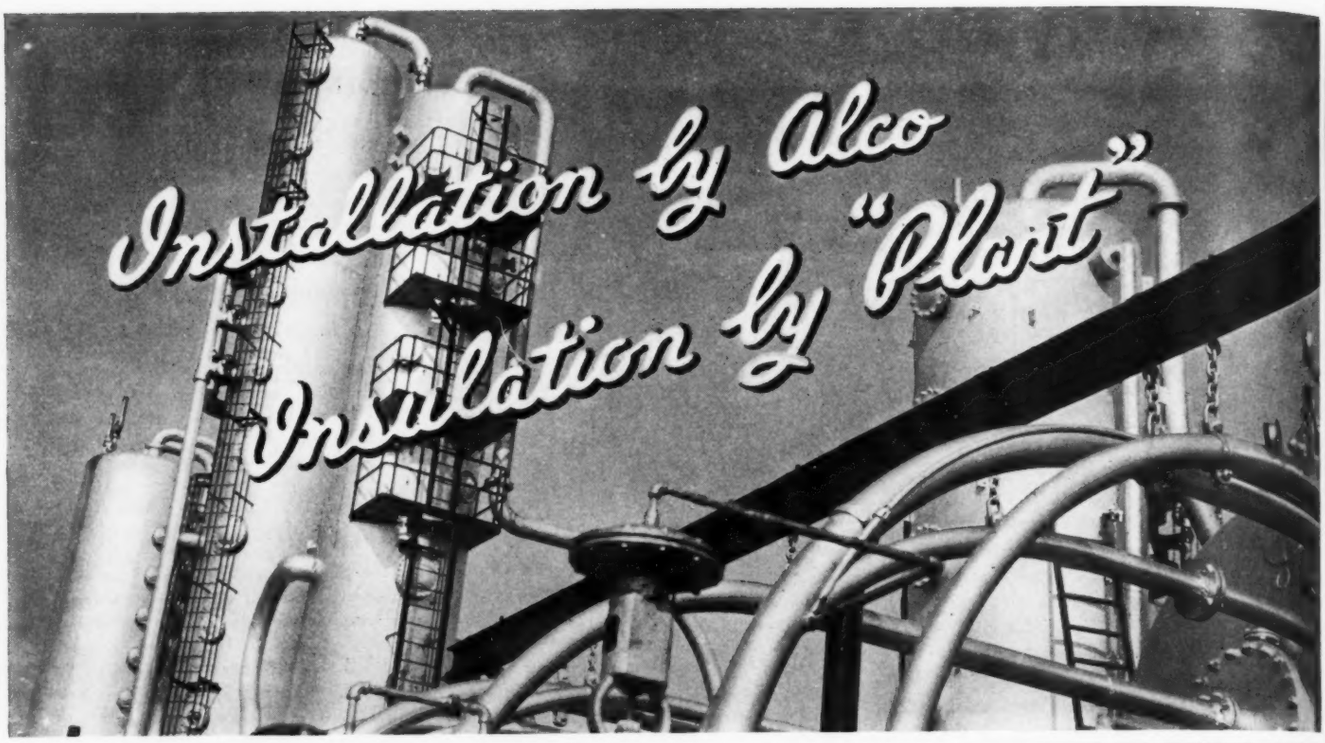

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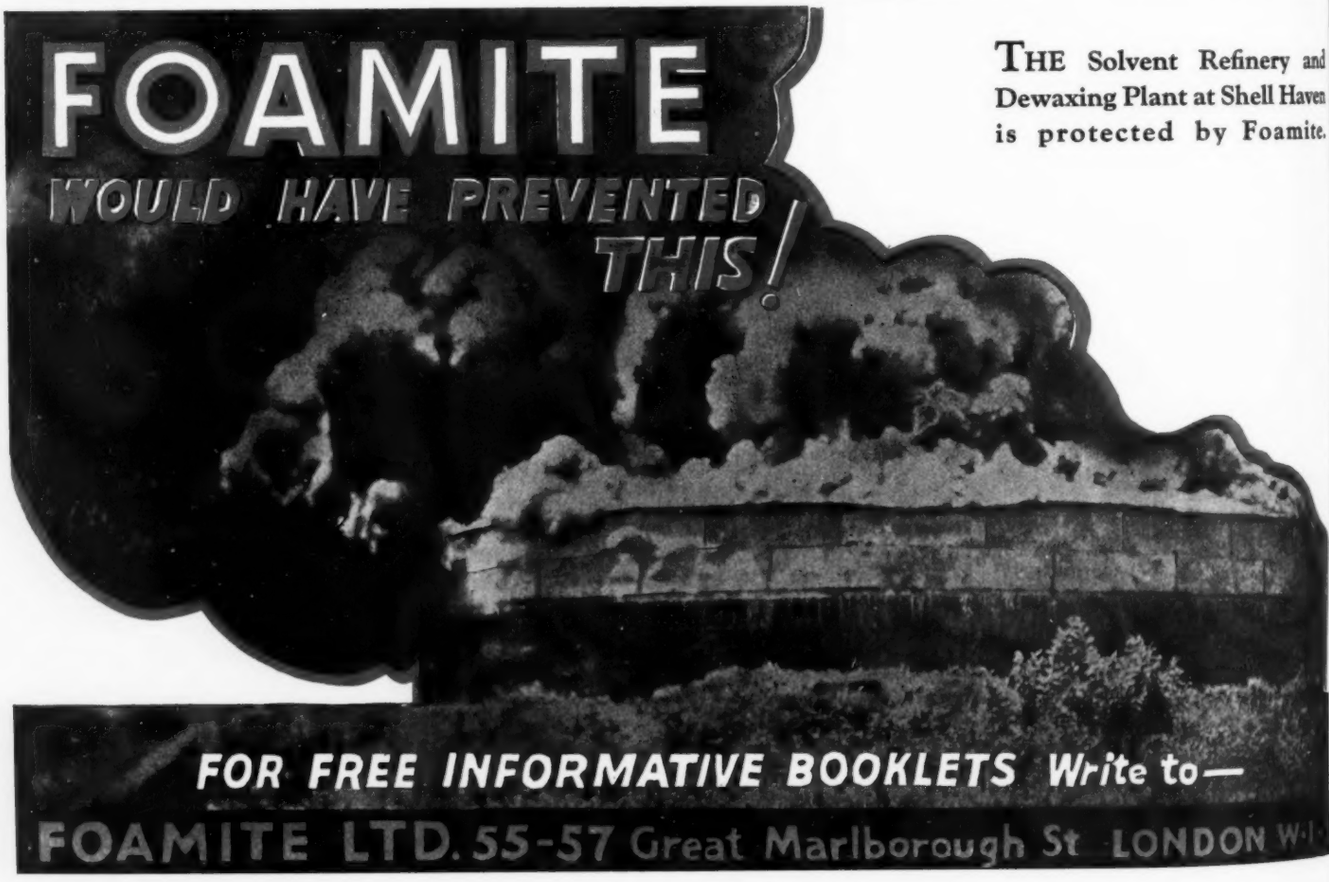

THE Solvent Refinery and Dewaxing Plant at Shell Haven is protected by Foamite.

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furfural at the top pass through exchangers and preheat the extract solution input.

Vapors from the bottom of the tower are brought into the furfural tower for re-rectification. Vapors containing little furfural are taken to condenser coolers and waterfree furfural is taken as a sidestream. Regenerated furfural is partially used for spraying the towers (raffinate and extract). Vapors of diluted furfural from the top of the furfural and raffinate towers are led to condensers and coolers, then to a tank where the liquid containing seven to eight percent furfural is used for spraying the furfural tower.

Operating Temperatures of Installation

Extraction tower:	
Top	100 deg. C.
Bottom	80 deg. C.
Raffinate tower:	
Top	98 deg. C.
Bottom	165 deg. C.
Furfural tower:	
Top	98 deg. C.
Bottom	165 deg. C.
Extract tower:	
Top	162 deg. C.
Lower part of top	187 deg. C.
Stripping:	
Top	98 deg. C.
Outflowing extract	185 deg. C.
Heating of raffinate solution in furnace	200 deg. C.
Heating of extract in furnace	230 deg. C.
Heating of distillate in exchangers	80 deg. C.
Heating of raffinate solution in vapor distillate heat exchangers	115 deg. C.
Heating of extract solution in vapor distillate heat exchangers	130 deg. C.

Employing selective treatment of lubricating oil, Soviet refineries will produce the following basic grades: transformer oil, spindle oil, machine oil, and motor oil "T". All other grades of lubricants will be obtained by blending.

Technological Indices of Operation

Consumption of:	
Fuel (from distillate)	4.9 percent
Fresh steam (from total steam*)	1.95 percent
Used steam (of total steam)	24.8 percent
Sea water (per ton of input)	235 tons
Furfural (Per ton of input)	0.25 percent
Electric power (per ton of input)	69 kw. hr.
Electric light (per ton of input)	0.5 kw. hr.
Loss of oil:	
Selective treating	20 percent
Acid contact treating	3.5 percent
Acid (to input)	2 percent
Bleaching earth (to input)	2 percent

*Fresh steam is used for pumps and to evaporate fuel in furnace: otherwise used steam is applied from the pumps, superheated to 250 deg. C. by superheaters placed in the refinery furnace.

This installation is for a capacity of 13 tons per day, and the yield from the raw material is 75 percent.

Raw furfural contains acids which may corrode the equipment, and must be neutralized with calcined soda and refined. The extract is heated by open flame, or mixed with fresh steam, and goes to the rectification tower, the top of which contains a partial condenser and the bottom a reboiler where the hot extract is circulated. The refining residue is a furfural which contains other fractions that boil at high temperature, and contains sodium salts which are removed in a separate installation.

When the new Russian solvent extraction lubricating oil refining plant described in this article was ordered and delivery made on time, it was discovered that there was no furfural to operate the installation.

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REFLEX and TRANSPARENT GAGES

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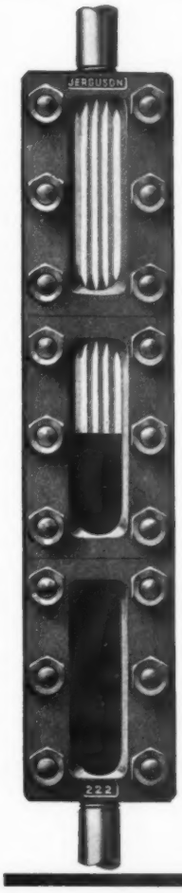

REFLEX GAGES provide maximum visibility:

The space above the liquid appears WHITE
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TRANSPARENT GAGES show the color density:

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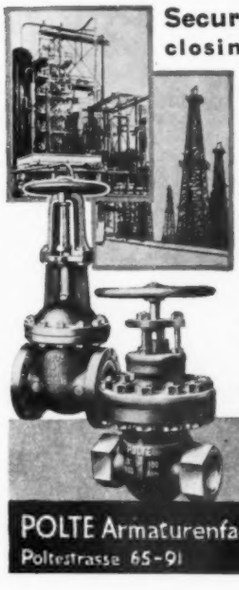

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